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(4) In June 1933, copies of these three proposals were submitted to the 88 editors of the *Journal* for an indication, by ballot, of their recommendations. After three ballots (June to Nov. 1933) in which practically all editors participated, a large majority of the whole Board voted to recommend that (a) each of the said three proposals be rejected, and that (b) the *Journal* be given directly to the Research Association.

[1] Gies: *Journal of Dental Research*—(a) 1933, xiii, p. 297, Aug.; (b) p. 521, Dec.; (c) 1934, xiv, p. 1, Feb.

(5) In November 1933, in formally announcing to the editors of the *Journal* and to the officers of the Research Association the foregoing result, we stated, in conformity therewith, "our readiness to transfer ownership of the *Journal of Dental Research* to the International Association for Dental Research as of January 1, 1934," and "our willingness to cooperate in transferring ownership *and management* as soon thereafter" as the Association might wish, and "as comfortably" for the Association as possible, provided the Association "decides to accept the gift."

(6) The President of the Research Association at once referred this notice to the Association's standing Committee of Three on the *Journal of Dental Research*, which recommended to the Council (Dec. 1933) that the proffered ownership be accepted.

(7) The Council, acting on this report, (a) voted (Jan. 1934) to recommend to the Association that ownership of the *Journal* be accepted; (b) transformed (Feb. 1934) the standing Committee of Three into a special Committee of Seven, to consider size and personnel of the first board of editors and matters of management, the report of this Committee to be presented at the meeting of the Association in March; and (c) instructed (Feb. 1934) the General Secretary to ascertain, and report to the Association, whether various dental societies would give financial coöperation.

(8) At the general meeting of the Association (March, 1934), where the foregoing reports and other matters were presented and reviewed, the Association voted, in accord with these recommendations, to accept ownership of the *Journal*. All conditions of further procedure and management were referred to the Council for study, decision, and early enactment. Successive issues of this *Journal* will reflect the evolution of the Council's expressed desires.

The dental societies now coöperating with the Research Association, to give the *Journal* adequate financial support, through subscriptions for all or some of their members, are these: (1) Academy of Stomatology (Philadelphia), (2) Allied Dental Council (N. Y.), (3) American Academy of Dental Science, (4) American College of Dentists, (5) American Stomatological Association, (6) Andrews (Robert R.) Society for the Promotion of Research (Dental School of Tufts College), (7) First District Dental Society of the State of New York, (8) Kings County Dental Society (N. Y.), (9) New York Academy of Dentistry, (10) Odontographic Society (Chicago). These societies are generously showing very practical interest in the advancement of dental research and in the strengthening of its effective agencies.

CHANGES IN TEETH FOLLOWING HYPOPHYSECTOMY

II. Changes in the Molar of the White Rat[1]

I. SCHOUR, B.S., D.D.S., M.S., Ph.D.,[2] and H. B. VAN DYKE, Ph.D., M.D.[3]

Chicago, Illinois

I. INTRODUCTION

In this study we investigated effects of hypophysectomy on the rat molar. This tooth resembles the human molar in its gross and microscopic anatomy, and in its limited growth. The animals were hypophysectomized, and cared for, in the laboratory of one of us (H. B. v. D.); the rest of the work and the writing of the paper were done by the other. We are deeply indebted to Dr. G. W. Bartelmez, who directed the anatomical phases, and helped very generously in carrying out the various stages, of the work. We are thankful to Drs. R. R. Bensley and F. B. Noyes for encouragement and suggestions. Miss Frances Schwab rendered valuable assistance in the preparation of the histological sections.

II. REVIEW OF LITERATURE

A survey of the literature indicates that no previous study of molars of hypophysectomized rats has been made. Hypophysectomy in dogs causes retarded eruption of teeth (Ascoli and Legnani, Aschner, Erausquin, Burnett, Koster and Geesink, Downs). Histologic studies made by Kranz, Erausquin, and Downs were negative. Erausquin reported no change in size of crowns but noted short roots, wide pulp-chambers, and wide apical foramina. The changes were most prominent in canines. Clinical literature yields repeated findings of anomalies in dentition in pituitary deficien-

[1] A preliminary report was presented at the tenth general meeting of the International Association for Dental Research: *Journal of Dental Research*, 1932, *12* p. 548; June. Also, at a joint meeting of the American College of Dentists with Section N of the American Association for the Advancement of Science, Boston, Dec. 29, 1933; *Jour. Amer. Coll. Dent.*, 1934, i, p. 49; April.

[2] Department of Dental Histology, University of Illinois, and Department of Anatomy, University of Chicago, Chicago, Illinois.

[3] Pharmacological Laboratory, University of Chicago, Chicago, Ill.

cies (Biedl). Possible association between paradentosis and disturbances of the anterior lobe has been suggested (Weinmann, Boenheim). The fact that many patients with pituitary disturbances do not present a clear-cut disturbance of the hypophysis alone makes it difficult to determine the exact rôle played by abnormal function of this organ.

III. MATERIAL AND METHODS

This study is based on twenty-two successfully hypophysectomized rats. Their age, at operation, ranged from 36 to 64 days; the interval between operation and death, 63 to 459 days (*table 1*). These animals were also used in a study of effects of hypophysectomy on the rat incisor (Schour and van Dyke, 1932b). Six animals were given replacement therapy (*table 2*). An operation was considered successful when there was no increase in spontaneous growth for months, and no spontaneous oestrous cycle for weeks or months. A study was also made of fifteen litter-mate controls, most of which had been unsuccessfully hypophysectomized (*table 3*). These, and also the unoperated litter-mate controls, showed no indication of hypophyseal deficiency. We accept this fact as evidence that the changes noted in the teeth were not due to operative injuries. We studied also six operated rats for which weight curves and oestrous cycles indicated only partial hypophysectomy (*table 4*).

Operations were performed by the parapharyngeal approach (technique of P. E. Smith). Histologic preparation was the same as that employed in the study of incisors (Schour and van Dyke, 1932b). Ground sections were prepared by sawing the tooth into three longitudinal divisions. One side of each division was ground, polished by hand, mounted on a disc with balsam; then ground on Black's apparatus (Black, 1924).

Radiographs of some animals were enlarged three times to facilitate gross study. State of eruption of molars was studied with a dissecting microscope. Some teeth, extracted and freed from investing tissues, were studied under a magnification of 40. Length of roots was measured with calipers under the microscope.

IV. GROSS FINDINGS

This study is based chiefly on findings in upper molars; conditions in lower molars are often obscured by caries. The mandibles were sectioned primarily for another study of lower incisors. Comparison of radiographs of experimental and control animals indicates no apparent differences in size or shape of coronal portions. However,

shorter root length, and wider pulp-chamber, pulp canal, and apical foramen, are indicated in molars of hypophysectomized rats. Mesiodistal width of sixteen upper molar groups (ten from experimental, and six from litter-mate control, animals)—obtained by measuring on enlarged (×3) radiographs the linear distance between the most mesial point of the first molar to the most distal point of the third molar—is practically the same for the experimental animals and their litter-mate controls. Root-lengths of fifteen upper molars from experimental animals—freed from investing tissues, and measured under a dissecting microscope with calipers—are 10–15 percent shorter than the corresponding roots for eighteen litter-mate controls. It was impossible to obtain quantitative data on width of pulp canals and apical foramina from radiographs or extracted teeth. Histologic data indicate, however, that pulp canals and apical foramina are somewhat wider in the experimental animals (*fig. 1*). Radiographs show that the distance between root ends of lower molars and lingual or concave surface of lower incisors is greater in experimental animals than in controls (*figs. 6* and *7*).

Radiographic and gross examinations of the lower molars show absence of caries-like destruction in animals that were not more than about 200 days old, and high incidence of extensive caries in both control and experimental animals above this age. Radiographic and gross examinations show no caries in upper molars at any age excepting the second molar of one experimental animal (Rat 113, *fig. 3*). We conclude that caries in experimental animals was not significantly different, in amount and quality, from that in litter-mate controls. Unfortunately we did not measure quantitatively the rate of eruption of molars, as was done for incisors in a previous study. Examination of upper molars with a dissecting microscope disclosed definite retardation of their eruption in the experimental animals (*figs. 3–5*), regardless of the fact that "elongation" might have been expected owing to lack of antagonists due to destruction of many lower molars by caries. The third molar, normally last to erupt and in some cases just becoming exposed at the time of operation, shows the greatest degree of retardation. The histologic findings corroborate the gross findings (*fig. 1*).

V. HISTOLOGIC FINDINGS

MOLAR OF NORMAL RAT. Detailed discussion of this phase is reserved for another occasion. Our findings confirm those of Erdheim (*fig. 13*). Occasionally the cementum surface is sprinkled with minute granules which

TABLE 1

Data on twenty-two successfully hypophysectomized rats; arranged in order of length of post-operative life

RAT				INTERVAL	GROUP	
No.	Age: days at operation	Killed or died	Age: days at death	Days: operation and death	Histologic findings; incisors[1]	Histologic and anatomic findings; molars
289	55	Died	118	63	I	II[2]
324	45	Killed	141	96	I	I[4]
314	46	Died	156	110	I	I[4]
265	50	Died	195	145	I	II
264	49	Died	216	167	I	II
317	46	Killed	213	167	I	I[4]
257	64	Died	242	178	II	III
199	49	Died	243	194	II	II
240	47	Died	254	207	I	II
221	44	Died	263	210	I	II
268	61	Killed	304	243	I–II[3]	I[4]
228	45	Died	296	251	III	II
144	41	Died	298	257	II	III
108	36	Died	309	273	III	III[2]
154	37	Died	329	292	III	II
216	39	Died	411	372	III	III
151	40	Died	420	380	III	III
258	64	Killed	476	412	II–III[3]	I[4]
186	50	Killed	478	428	III	III
156	41	Killed	473	432	III	III
111	40	Died	483	443	III	III
113	36	Killed	495	459	III	IV[2]

[1] X-ray findings were positive in each case.

[2] Selected for detailed histologic description of molars as representative of the corresponding group.

[3] On the border line of the indicated group, possibly because these animals received 61 injections of growth hormone, which may have retarded histo-pathologic changes.

[4] These animals were given replacement therapy—injections of phyone.

stain like cementum. At or near the cementum surface, and within, periodontal fibers that take the eosin stain sometimes show in cross or oblique section small, usually round, hematoxylin-staining globules or

TABLE 2

Data on six successfully hypophysectomized rats that received replacement therapy[1]

RAT NO.	PERIOD OF INJECTION	
	Number of successive days	Days following hypophysectomy
314	20	54–73
324	20	77–96
268	21	125–145
317	12	139–150
268	20	167–186
268	20	224–243
258	21	294–314
258	20	336–355
258	20	393–412
186	17	412–428

[1] Injections of the hormone of the anterior lobe of the hypophysis.

TABLE 3

Data on fifteen litter-mate controls, most of which were unsuccessfully hypophysectomized[1]

RAT NO.	LITTER-MATE CONTROL: TO	KILLED OR DIED	AGE: DAYS AT DEATH
323	324	Killed	141
312	314	Killed	176
318	317	Killed	213
202	199	Killed	253
238	240	Killed	257
148	144	Died	279
270	268	Killed	304
219	221	Killed	305
168	166	Killed	364
155	151, 152, 154	Killed	370
146	144	Died	377
112	108, 111, 113	Killed	394
157	156	Killed	473
255	257, 258	Killed	476
214	210, 216	Killed	561

[1] Histologic and radiographic findings were normal in each case.

TABLE 4

Data on six rats that were hypophysectomized with only partial success[1]

RAT				INTERVAL: DAYS BETWEEN OPERATION AND DEATH
No.	Age: days at operation	Killed or died	Age: days at death	
230	47	Killed	301	254
175	47	Died	348	301
166	34	Died	364	330
184	49	Died	459	410
152	40	Killed	471	431
210	42	Killed	561	519

[1] Partial success of the hypophysectomy was evidenced by an intermediate disturbance in oestrous cycles and an irregular weight-curve.

granules, which are confined to the cross-sectional areas of the fibers. In some, granules appear to fuse so that the eosin-staining portion is diminished in area and confined to a fine peripheral border. These deep-blue staining areas can sometimes be traced lengthwise in the fibers, very likely assuming a diminutive form of the fibers in which they are found. We agree with Erdheim that these areas are possibly calcified portions of periodontal fibers. A similar phenomenon can sometimes be observed in cross and oblique sections of periodontal fibers as they approach and become embedded in alveolar bone. Epithelial rests are occasionally found in periodontal membrane near the root surface at the bifurcation or the apical region. Mast cells, commonly found in the connective tissue of the rat, are normally absent in pulp and periodontal membrane. In control animals, enamel that is not exposed to saliva is usually lined by epithelial attachment which shows no papillae. Pocket formation apparently is not common; when present is readily associated as a rule with traumatic injury by a foreign body (Skillen).

One should distinguish between histology of the normal molar of the rat, and histology of the molar of the *so-called* normal animal, that is, the rat given diet and care that at present are regarded as adequate. One is likely to find, in histologic sections of molars of "normal" rats, at least occasional abnormalities, such as slight resorption of cementum, particularly near the cemento-enamel junction; beginning of pocket formation; or degenerative changes in the pulp. As a rule these abnormalities can be traced to some observable causative factor, such as caries, traumatic injury of gingivae, or involvement of periodontal membrane. In two control animals, we found one instance of early resorption of enamel next to the cemento-enamel junction. We are unable to explain this condition.

HISTOPATHOLOGY OF THE MOLAR OF THE HYPOPHYSECTOMIZED RAT. Although each animal presents an individual reaction, a common pattern was readily recognized. On the basis of histologic findings, without reference to duration of post-operative life, our material can be divided into three groups: *Group I* presents, as a whole, only *slight* or practically no alterations. *Group II* presents disturbances of *medium* severity. *Group III* presents disturbances of *great* severity.

Group I includes (*a*) *six* animals hypophysectomized with only partial success (*table 4*); and (*b*) *five* of the six hypophysectomized rats given replacement therapy (*tables 1* and *2*). While there appeared to be no correlation between histologic findings for Group I, and post-operative life (*table 1*), differences in degree of severity of histologic changes for Groups II and III could be readily explained on the basis of their post-operative life. The

animal that showed changes of greatest severity was Rat 113, which had a post-operative life of 459 days—the longest in the series. The *six animals* of Group I that were hypophysectomized with only partial success (*table 4*) showed a histologic picture that was normal, excepting imperfect calcification of cementum in three rats. Apparently, because of the length of post-operative life, any other changes following operation left no record in the histologic sections. The *five animals* of Group I that were given replacement therapy ranged, in post-operative life, from 96 to 412 days (*table 2*). There is an interesting correspondence between groupings according to findings in incisors, and those in molars. However, replacement therapy was not merely more effective in reducing the severity of changes in molars than in incisors, but apparently also produced a practically *normal* histologic picture in Rats 258 and 268, each of which was given three periods of about 20 daily injections of the hormone of the anterior lobe of the hypophysis; and a relatively slightly *abnormal* picture in Rats 314 and 324, given only one period of 20 daily injections. In Rat 186, 17 daily injections appeared to have no effect on histologic conditions following hypophysectomy. This lack of reaction may be readily associated with the fact that the hormone was administered during post-operative days 412–428. This animal also showed no response in rate of eruption, which was zero before replacement therapy and remained unchanged (Schour and van Dyke, 1932a).

Group II. The findings for Rat 289 are representative. At operation it was 55 days old; its post-operative life was 63 days, the shortest in this series. There was definite retardation in eruption of molars, especially the third. This observation is confirmed by conditions in histologic sections where the crest of the gingiva at the distal side of the upper third molar is at the level of the occlusal surface. This relationship is similar to, but less prominent than, that in *fig. 1.* In a few sections, epithelial attachment is absent near the cemento-enamel junction. At the distal surface of the third molar, resorption at the enamel and the dento-enamel junction is similar to that in *fig. 12.* Pulp has a blood supply within normal range. In the third molar, the pulp chamber shows an abscess. Blood supply of the periodontal membrane appears to be reduced. Epithelial rests are large and more numerous than normally. Cementum shows considerable resorption at the bifurcation level and at the sides of the root (*figs. 10* and *19*). In some fields, repair of resorbed areas has not yet apparently taken place. Minute globules that stain like cementum are occasionally seen at the surface of the coronal third of the root. These seem to be within the normal range. The cementum hyperplasia at the

cemento-enamel junction is normal in appearance. Alveolar bone shows an abnormal amount of resorption, and a greater than normal number of giant cells. At the bifurcation level, new actively forming bone-spicules occur in the periodontal membrane opposite areas of cementum resorption (*fig. 10*).

Group III. The findings for *Rat 108* are representative. At operation, it was 36 days old; it died 273 days thereafter. There was definite retardation in eruption of upper molars, especially the third (*fig. 4*). This observation is confirmed in the histologic sections: mesio-distal sections show that the crest of the gingiva distal to the third molar is at the level of the occlusal surface (*fig. 1*); transverse sections show that the gingival crest buccal to the third molar is also at about the occlusal level (*fig. 18*). Epithelial attachment is often absent at the cemento-enamel junction. Enamel at these places is usually separated from adjacent connective-tissue by a cementum spur (*fig. 20*). Resorption of enamel was not observed. Pulp and periodontal membrane show poor blood-supply (*fig. 1*). Epithelial rests are very numerous, proliferative, and larger than normally (*figs. 1* and *16*). Cementum shows only slight resorption. Secondary cementum is considerably less than normal in amount (*fig. 1*). The surface near the cemento-enamel junction is often sprinkled with minute globules that stain like cementum. Cementum hyperplasias are present at the cemento-enamel junction and normal in appearance. Alveolar bone shows prominent resorption and an abnormally large number of giant cells. Cementing lines are crowded and more numerous than normally.

Rat 113 showed the most severe changes; at operation it was 36 days old; its post-operative life was 459 days, the longest in this series. There was retardation in eruption of molars, particularly the third (*fig. 3*), which had begun to erupt at the time of the operation. Epithelial attachment is commonly absent at the cemento-enamel junctions. Enamel at these places is usually lined by a cementum spur or is resorbed, resorption extending only into part of the enamel or beyond the dento-enamel junction into dentin (*fig. 12*); also seen in ground sections (*fig. 11*). The pulp shows a reduced blood supply (*fig. 14*), when compared with a corresponding field for a control animal (*fig. 17*); in some teeth, is necrotic. The periodontal membrane also has a reduced blood-supply. Epithelial rests are numerous and prominent, some having become cystic; a few appear to be calcified. Globules that stain like cementum occur frequently; abundantly at the cementum surface (*figs. 14* and *15*); some, in periodontal tissue. In *fig. 9*, they are arranged in a bead-like row parallel with the course of periodontal fibers. In an oblique section of periodontal membrane, and of the cemen-

tum surface of corresponding sections, one can trace globules as they appear in the middle of fibers, singly or in clusters. Nearer the cementum surface, some appear to fuse; at the surface, the entire cross-sections of some periodontal fibers appear to have taken hematoxylin stain. These conditions indicate pathologic formation of primary cementum, and calcification of periodontal membrane fibers (*fig. 2*). In periodontal membrane cementum-like structures are larger and fewer than the globules at the surface, and react in similar manner to hematoxylin. They are spherical or oval in shape (*fig. 15*), and usually arranged in the direction of periodontal fibers. Alveolar bone shows in many fields crowded arrangements of cementing lines, and gives the appearance of bone that has undergone much resorption and apposition (*fig. 15*). In oblique and tangential sections of the surface (*fig. 8*), hematoxylin-staining globules occasionally occur within periodontal fibers themselves, which, when traced, appear to show conditions similar to but less striking than those for the cementum surface, in *figs. 2* and *15*. Apices of a distal root of the third molar and a mesial root of the second molar are so close that interproximal alveolar bone is absent; in some sections these roots are separated only by fine strands of connective tissue. Ground sections show normal dentin. Secondary dentin is present in only slight amount. Enamel is normal except in the gingival third, where there are areas of prominent resorption (*fig. 11*), and regions that indicate partial decalcification corresponding to findings in decalcified sections (*fig. 12*).

VI. DISCUSSION OF RESULTS

Rate of eruption. The evidence (*figs. 1, 3–5*) shows that rate of eruption of *molars* in hypophysectomized rats was retarded soon after operation. The state of eruption of molars at operation tends to be the permanent condition, particularly for the third molar, which erupts at about the thirty-fifth day. Eruption preceded the operation in each case, but for only a short period (*table 1*). These findings agree with those for *incisors*, eruption of which was definitely retarded and finally stopped entirely. We feel justified in assuming that in successful hypophysectomy of rats at 25 days or earlier, the third molar would not erupt throughout a normal duration of post-operative life.

Epithelial attachment. Except for some occasional slight inflammatory reaction due to trauma, the epithelial attachment is normal near the gingival crest. Toward the cemento-enamel junction, however,

it often shows atrophy or is entirely absent. This is similar to the fate of enamel epithelium in the anterior zone in the incisor of the hypophysectomized rat. Pocket formation is not observed except in the presence of local traumatic injury, usually foreign-body implantation.

Enamel as a whole is normal, excepting areas of resorption and areas adjacent thereto. Enamel hypoplasia, common in the incisor of the hypophysectomized rat, was not observed; the period of enamel formation of the molar apparently ended before the operation (*table 1*). Ground and decalcified sections (*figs. 11* and *12*) indicate that the resorption process attacks the surface first in such a manner that enamel appears to be undergoing decalcification. The region of total resorption is smaller than that of decalcification; areas of complete resorption in decalcified sections are often surrounded by remains of organic matrix (*fig. 12*). This destructive process is unlike caries, and occurs at the level of a tooth embedded in soft tissue and not exposed to the oral cavity. In some cases, resorption extends beyond the dento-enamel junction, and is associated with absence of enamel epithelium. Enamel that is not exposed to the oral cavity is normally bounded by epithelial attachment (Gottlieb). When the latter is lost, enamel is in direct contact with connective tissue. A cementum spur may be laid down by connective tissue, so that the cementum intervenes between the latter and enamel. Resorption of enamel covered by epithelial attachment or cementum was not observed. Absence of resorption in Rat 108 may thus be associated with more or less constant presence of a cementum spur wherever epithelial attachment is absent (*fig. 20*). Giant cells have not been found in the bays of enamel resorption. These cells may not be essential to this process. Since we know little concerning enamel formation, and of the relation of the time of its completion to that of eruption—and since giant cells have not been observed—"resorption" might be supposed, at least in some instances, to be *hypoplasia*. However, the fact that dentin is also involved confirms the view that the process is resorption. Without giving any detailed information, Black (1884) alluded to resorption in enamel of third molars that were retarded in eruption. Deposition of cementum upon enamel, or resorption of the latter following loss of enamel epithelium, was de-

scribed by Kotanyi for retained human teeth. Orban reported similar findings in erupted human teeth.

Dentin as a whole is normal. Secondary-dentin formation appears to be less than normal; its rate of growth is retarded, as evidenced by wider pulp chamber, pulp canal, and apical foramen. Width and contour of the dentinoid border are within normal range. Resorption of dentin, when present, appears to be only secondary to that of its covering of enamel or cementum. Dentin stains with hematoxylin more deeply in the experimental than in the control material under identical conditions of preparation (*figs. 14* and *17*).

Cementum. In cementum there was a reaction that cannot be explained on the basis of mere retardation in growth. Resorption of cementum in the rats of shorter post-operative life (*figs. 10* and *19*) is puzzling, for there is evidence of constructive apposition throughout post-operative life. Secondary-cementum formation was considerably diminished (*fig. 1*), but apparently continuous and relatively free from resorption. Abnormal sprinkling of hematoxylin-staining globules of various sizes at the cementum surface and in adjacent periodontal membrane, in some animals of advanced post-operative life (*figs. 9* and *15*), suggests a pathologic condition of over-calcification, probably disturbance and exaggeration of a normal phase in the calcification of periodontal fibers and in cementum formation. Final explanation of these globules awaits microchemical determination whether they are calcified. Cementum hyperplasia at the cemento-enamel junction is common, but not as vigorous as in some controls. Frequent occurrence of cementum spurs of varying lengths and thicknesses, depending on the extent of atrophy of the epithelial attachment and time available for the reaction, indicates constructive reaction by connective tissue. When this reaction does not occur, resorption of enamel tends to take place.

Periodontal membrane. Numerous and proliferative epithelial rests indicate active reaction. In Rat 108, where epithelial rests were more numerous than in any other, resorption of cementum was less prominent than in most experimental animals. It is doubtful whether these two facts may be associated. Blood supply was reduced. In two animals, mast cells were found in the periodontal membrane.

Pulps showed reduced blood-supply and persistence of juvenile size (*fig. 1*). In some cases there was atrophy, calcific degeneration, or necrosis. These degenerative changes may be internal, or hematogeneous, in origin, since decay and exposure of pulp were practically absent in upper molars. Involvement of periodontal membrane was noted in a few instances.

Epithelial changes are interesting. The epithelial attachment, which normally is persistent, tends to disappear (*fig. 20*); epithelial rests, believed to be non-functional, increase in number and size (*fig. 16*).

Alveolar bone, in the animals of shorter post-operative life, shows some resorption and giant cells. After longer post-operative life, alveolar bone presents, in many fields, an increased number and irregular crowded arrangement of cementing lines, giving the appearance of bone that has undergone an unusual amount of apposition and resorption. In advanced stages, the bone is sclerotic and reminds one of "mosaic" bone as described by Schmorl. This disturbance may be associated with endocrine involvement, possibly parathyroid, or with a general severe set-back. Bone marrow of alveolar bone tends to be fibrous, and often occupies smaller spaces than normal. In one instance, periodontal membrane next to the alveolar crest shows a showering out of calcified bodies that are similar to those seen more often near the cementum (*fig. 15*). Bone apposition is continuous throughout postoperative life. This may be surprising in view of the fact that skeletal growth stops almost immediately after hypophysectomy. However, apposition of alveolar bone is not comparable with increase in length of long bones; it is an expression of high adaptability to function and stress. There appears to be an intensive but unsuccessful effort to establish a balance between resorption and apposition of bone, and resorption gains ground. The fact that abnormal resorption occurs in enamel and cementum strengthens this view.

Disturbances in calcification. There is apparent contradiction between indications of under-calcification in animals of shorter post-operative life, and of over-calcification in animals of longer post-operative duration. In some respects a similar sequence of events has been found, however, in various types of experimental hyper-

parathyroidism (Selye, Jaffe, Schour and Ham) and in hypervitaminosis D (Weinmann, Schour and Ham). Recent literature has brought increasing indications of involvement of parathyroids in the hypophysectomy picture. Atrophied parathyroid glands have been found in hypophysectomized dogs (Houssay and Sammartino). Cushing suggests an interrelationship between hypophysis and parathyroids. Recently Barker found a suggestion of tetany in hypophyseal dwarfism. Koster and Geesink, and Evans, refer to hypocalcemic conditions in absence of the hypophysis, while Gerschmann reports normal calcium content in hypophysectomized dogs. Considerable research will be necessary to evaluate the clues found in dental changes.

Incidence of paradentosis. The association indicated in recent literature between diffuse atrophy of alveolar bone (Gottlieb) or paradentosis, and disturbances of the anterior lobe of the hypophysis, is not apparent in this investigation. Molars of experimental rats show susceptibility to caries like that of litter-mate controls. Findings of continuous resorption and apposition of alveolar bone, and continuous (although slowed down) apposition of cementum, indicate, in spite of resorption of root surface, adjustments that make firm attachment of molars possible. It was difficult to establish the degree of resorption of alveolar bone, but apparently the process was not sufficient to loosen teeth. The height of the alveolar crest is not lower than in controls. Molars of completely hypophysectomized animals appear to be well embedded. Periodontal-membrane fibers are intact. Extraction of teeth for purposes of gross study was difficult. Pocket formation, downward growth of epithelium, and inflammatory reaction are rare, and can usually be associated with traumatic injury by a foreign body. In the latter case, there is locally produced "paradental pyorrhea," similar to but less intense than that described by Gottlieb (1922) in the rat molar. It is quite possible, of course, that conditions in rat molars are significantly different from those of human molars in respect to susceptibility to diffuse atrophy.

Comparison of changes following hypophysectomy, in incisors and molars. The reactions of molars and incisors are fundamentally identical. Practically all essential differences may be associated with physiological differences between the two types. *Incisors* grow rapidly throughout life; undergo modifications not only in size but

also in shape; alveolar bone is constantly adjusted to maintain firm attachment. *Molars* are limited in growth. The hypophysis was removed after most of this limited growth had already occurred. Hence, changes were less severe than, and in some respects different from, those in incisors, and replacement therapy was more successful.

Causal relationship between hypophysectomy and disturbances in rat incisors. One may reason that changes in incisors of hypophysectomized animals may be due primarily to severe, general constitutional setback. We feel justified in concluding, however, that changes in dental tissues, as reported, resulted primarily from hypophysectomy, for reasons discussed in a previous report (Schour and van Dyke, 1932b).

Possible basis for changes following hypophysectomy. The fact that all endocrine organs may be closely interrelated suggests the possibility that, in removing the hypophysis, one disturbs the parathyroids, which play an important rôle in calcium metabolism, and the removal of which definitely disturbs tooth development. However, incisors of hypophysectomized rats present a picture which as a whole is different from and, in respect to calcification, opposite that of parathyroidectomized rats. In the latter, dentin is deficient in calcification and the tooth is so weak that fractures are common (Erdheim). Following hypophysectomy, dentin usually shows a normal dentinoid border, and, insofar as it constitutes a greater proportion of the tooth mass than normally, strengthens the tooth beyond normal. Parathyroids therefore do not play a primary rôle in this problem, although they probably play a secondary rôle. We cannot entirely exclude the possibility that vitamins may also be involved. Although the animals received an adequate diet, certain vitamins may not be utilizable. Dental changes following hypophysectomy are primarily disturbances in growth. Todd pointed out that growth consists of two phases: increase in dimension and change of proportion. Growth disturbances produced experimentally by removal of the hypophysis confirm Todd's definition: teeth or parts of them are smaller, rate of eruption is retarded, and juvenile proportions persist.

Our histological findings can be explained on the basis of (*a*) retarded rate of growth of dentin, cementum, and alveolar bone; and (*b*) vascular disturbances. Either *a* or *b* may be the primary factors.

(*a*) Retarded rate of apposition of dentin accounts for wider pulp-chambers, pulp canals, and apical foramina, and consequent persistence of their juvenile character. Slowing down in rate of formation of secondary cementum at apices of molars may be largely responsible for shorter roots. Insofar as growth of tooth substance, and particularly formation of secondary-cementum, contribute to eruption of molars (Gottlieb 1922), their retarded rates result in partial retention of molars and thus perhaps contribute to atrophy of epithelial attachment, and localized resorptions of enamel. (*b*) The striking disturbance, reduction, and occasional disappearance of what normally is a characteristic and exceedingly rich blood-supply, suggest that the primary factor in this process is a circulatory disturbance, which in turn produces the alterations herein described.

VII. SUMMARY

Effects of hypophysectomy on molars of white rats have been studied in twenty-two completely hypophysectomized animals (63 to 459 days after operation) and fifteen litter-mate controls in respect to rate of eruption, and gross and microscopic alterations. The findings were retarded eruption; persistence of juvenile characteristics, shorter root lengths, and wider pulp-chambers, pulp canals and apical foramina; histopathologic changes; disturbances in calcification; vascular disturbances.

The changes are progressive. The actual conditions in a given case naturally depend on the time elapsing between operation and death.

Replacement therapy produced more or less complete recovery of the histologic changes in molars, depending on number of phyone injections.

The data throw interesting light on various phases of the growth and eruption processes of teeth.

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PLATES

PLATE 1

FIG. 1. Mesio-distal section of upper second (M_2) and third (M_3) molars of hypophysectomized Rat 108. This rat died at age of 309 days; histologic picture like that of much younger animal. Retarded eruption of third molar indicated by common level of distal gingival margin, *gm*, and occlusal surface of tooth. Note in third molar, atrophy of epithelial attachment, *ept;* height of pulpal horns, *ph;* reduced blood supply of gingivae, periodontal membrane, and pulp; increase in number and size of epithelial rests, *epr.;* wide pulp-chamber, pulp canal, *p;* and apical foramen, *af.;* and scant amount of secondary cementum, *sc*. *Figs. 16* and *20* taken from corresponding fields. *Fig. 18* taken from transverse section near occlusal surface of third molar. Compare with *fig. 13*, taken from control animal. Note level of alveolar crest in relation to cemento-enamel junction, and compare with corresponding relationship in *fig. 13*. × 18.

FIG. 2. Semi-diagrammatic reconstruction of oblique section of root of hypophysectomized Rat 113, tracing appearance of fibers and fibroblasts in periodontal membrane, and of fibers in cementum, *c;* dentin, *den;* hematoxylin-staining globules or granules, *gl;* oblique section of fibers, *of;* oblique section of fibroblasts, *ofb;* periodontal membrane, *pdm;* transverse section of fibers, *tf;* transverse section of fibroblasts, *tfb*. × 600; approximately.

FIG. 3. Drawing of occlusal and somewhat lingual view of upper left second (M^2) and third (M^3) molars of hypophysectomized Rat 113; litter-mate of Rat 108; lived 459 days after hypophysectomy. Note retarded eruption of teeth and caries in second molar. Compare with state of eruption in normal mature rat, *fig. 5*. × 7.5.

FIG. 4. Drawing of occlusal and somewhat lingual view of upper left first (M^1), second (M^2) and third (M^3) molars of hypophysectomized Rat 108; litter-mate of hypophysectomized Rat 113. Note retarded eruption of teeth, particularly third molar, and compare with *fig. 5* of normal rat; also with *fig. 1*. × 7.

FIG. 5. Drawing of occlusal and somewhat lingual view of upper left first (M^1), second (M^2), and third (M^3) molars of normal mature rat. Compare state of eruption of molars with *figs. 3* and *4*. × 7.

FIG. 6. Radiograph of molars of control Rat 202; 253 days old. Note distance between root-ends of lower molars and lingual surface of lower incisor. Compare with *fig. 7*. × 2.4.

FIG. 7. Radiograph of molars of hypophysectomized Rat 144; lived 257 days after operation. Note distance between root-ends of lower molars and lingual surface of lower incisor. Compare with *fig. 6*. × 2.4.

FIG. 8. Photomicrograph of tangential section of alveolar bone of hypophysectomized Rat 221. Note hematoxylin-staining globules, *gl*, in cross-section of periodontal fibers, *f*, embedded in alveolar bone. × 1550.

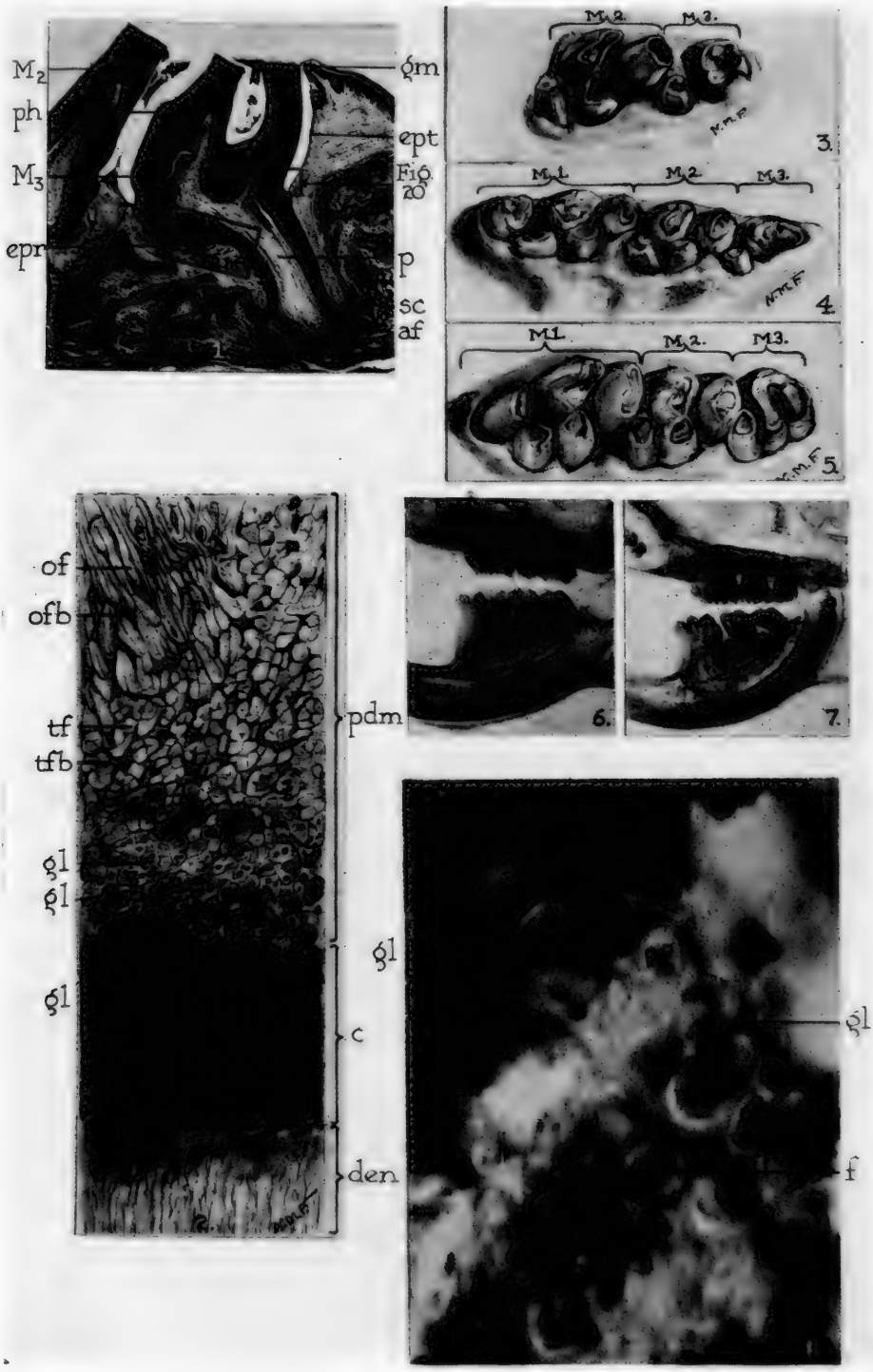
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PLATE 2

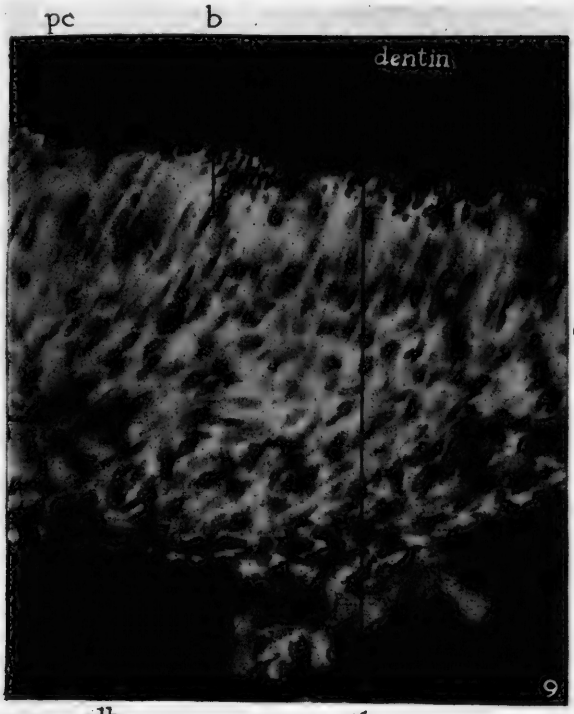
FIG. 9. Section of upper right molar of hypophysectomized Rat 113. Note alveolar bone, *alb;* numerous globules, *gl*, at surface of primary cementum, *pc*, especially bead-like row at *b*, extending into periodontal membrane. × 400.

FIG. 10. Section of upper molar of hypophysectomized Rat 289; lived 63 days after operation. Note resorption of cementum, *res*, at bifurcation level; recently formed spicules of bone, *b;* and alveolar bone, *alb*. × 95.

FIG. 11. Photomicrograph of ground section of upper left first molar of hypophysectomized Rat 113. Resorption bay, *res*, filled with partially decalcified enamel and connective tissue: *en*, enamel; *c*, cementum. × 210.

FIG. 12. Transverse section at level of cemento-enamel junction of upper molar of hypophysectomized Rat 111; litter-mate of Rats 108 and 113; lived 443 days after operation. Note resorption bay, *res*, extending to dento-enamel junction (above) and smaller resorption area of enamel (below); cementum, *c;* organic remains of enamel, *org*, on either side of resorption area and enamel space, *ens*. × 190.

FIG. 13. Mesio-distal section of upper right first molar of Rat 202; litter-mate (control) of Rat 199—253 days old. Note height of alveolar bone, *alv;* primary cementum, *pc;* constriction of pulp chamber, pulp canal, *p*, and apical foramen, *af;* secondary dentin, *sd*, and secondary cementum, *sc*. Compare with *fig. 1;* hypophysectomized animal. × 28.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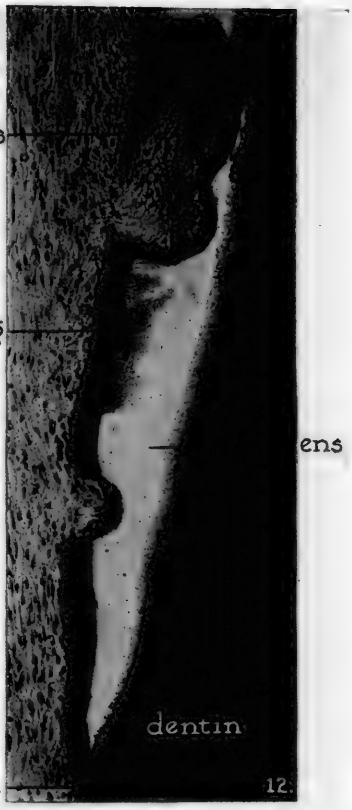
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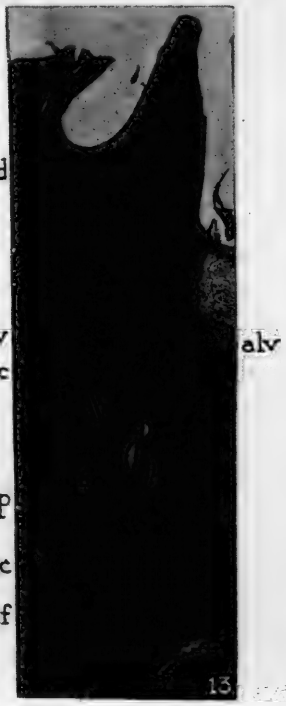
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PLATE 3

FIG. 14. Photomicrograph of section of root of upper right second molar of hypophysectomized Rat 113; lived 459 days after operation. Note numerous globules, *gl*, at surface of primary cementum, *pc*, and cementicle-like structures in periodontal membrane, *pdm*, at right side; reduced blood supply of pulp, *p;* absence of odontoblast and dentinoid layer, and apparent interruption of dentin formation, *di*, in lower half of root at left side of pulp; cementum hyperplasia, *chy*, and cementum spur next to it; secondary cementum, *sc;* and alveolar bone, *alb*. *Fig. 15* taken from field indicated. Compare with *fig. 17*. × 70.

FIG. 15. Photomicrograph at higher magnification of field indicated in *fig. 14*. Note alveolar bone, *alb;* cementicle-like structures, *ce*, in periodontal membrane, *pdm;* dentin, *den;* numerous globules, *gl*, at surface of primary cementum, *pc*. × 235.

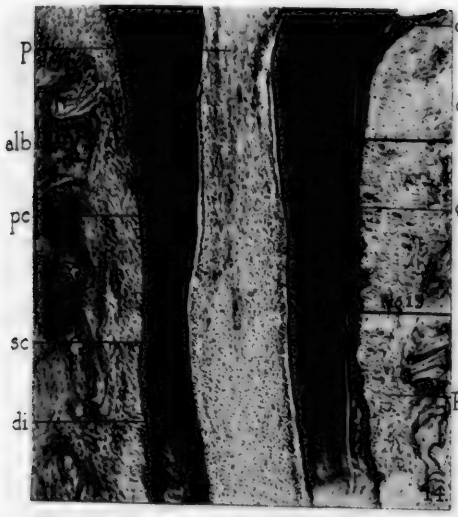
FIG. 16. Photomicrograph at higher magnification of field indicated in *fig. 1*. Note number and proliferation of epithelial rests, *epr;* reduced blood-supply of pulp; and periodontal membrane, *pdm*. × 140.

FIG. 17. Photomicrograph of section of root of upper molar of normal Rat 146; litter-mate (control) of hypophysectomized Rat 144. Field corresponds to that in *fig. 14*. Note rich supply of blood of pulp, *p*, and periodontal membrane, *pdm;* dentin, *den;* primary cementum, *pc;* alveolar bone, *alb*. × 70.

FIG. 18. Transverse section slightly below level of gum margin of upper right third molar (M^3) of hypophysectomized Rat 108. Section prepared from same block as that of *fig. 1*. Retarded eruption indicated by common level of papillary layer of gum margin, *pgm*, and pulpal horns, *ph*. Note dentin, *den*, and space, *ensp*, formerly occupied by enamel, but lost in decalcification.

FIG. 19. Oblique section of root of upper molar of hypophysectomized Rat 221; lived 219 days after operation. Note resorption of root, and scant blood-supply of periodontal membrane. × 90.

FIG. 20. Photomicrograph of corresponding field indicated in *fig. 1*. Note cementum spur, *csp;* absence of epithelial attachment lining enamel space, *ens;* and primary cementum, *pc*. × 215.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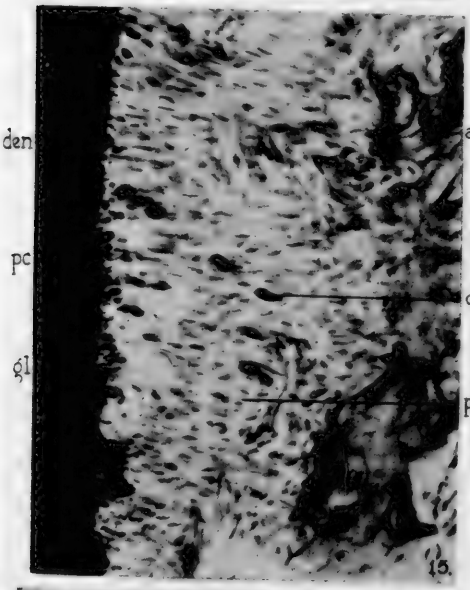
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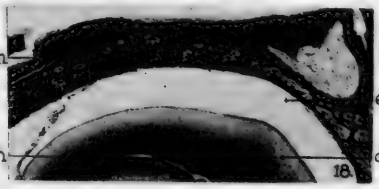
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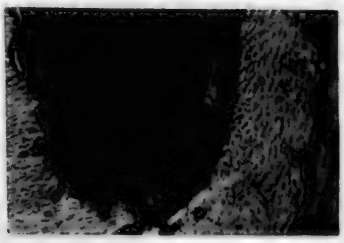

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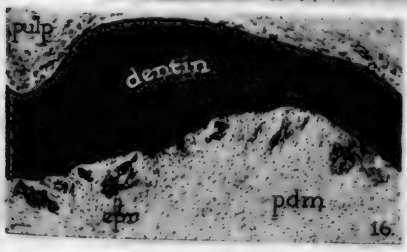
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16.

PERMEABILITY TESTS ON TEETH WITH PULPAL INVOLVEMENT[1]

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Tests of the permeability of teeth may be made to compare teeth of youth, where diffusional processes are involved in active metabolism, with teeth of maturity, where metabolic activities are greatly reduced or absent. Experiments have shown that irritations cause obliteration of dentinal tubules. Tests may therefore be made to determine the extent of such changes, to learn whether teeth under certain conditions are incapable of reacting to irritation. The last mentioned aim is the basis of this report on teeth that were extracted because of caries. In tests of this kind it is desirable to depend on physical forces in diffusional phenomena, such as osmotic pressure and capillarity, rather than on chemical affinity for components of tooth tissues. If the disclosing fluid is properly selected, physical forces cause relatively quick impregnation of interstices and areas of loose molecular structure. Chemically active stains, on the other hand, may vitiate the experiment by combining with normal tissue.

Experience has shown that alcoholic basic fuchsin, early used by Caush, fulfills reasonable requirements. It enters the interspaces, yet does not combine with mature intact enamel, cementum, or dentinal ground-substance, after weeks of exposure. Results due to its action are therefore especially noteworthy. Experiments of this kind were undertaken on a small scale in 1916,[2] and continued since 1929. The ensuing observations suggested the concept of "tooth maturation," first presented in 1930. The study of maturation has graphically demonstrated the existence of the physiologically scle-

[1] Work supported, in part, by a grant from the Research Commission of the American Dental Association. Presented at the meeting of the International Association for Dental Research, Chicago, Ill., March 17–18, 1934.

[2] Beust: Micro-biologic aspect of some dental inflammations. *Dental Summary*, April, 1918; p. 276.

FIG. 1. Halved tooth with chromophobic crown.

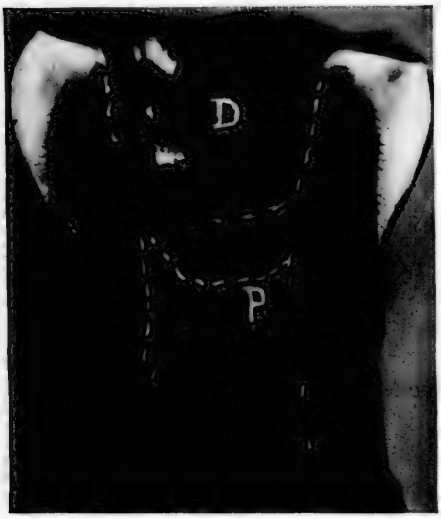

FIG. 2. Decayed tooth; chromophobic dentin completely lacking. *D*, decay; *P*, pulp cavity.

FIG. 3. Decayed tooth with slight amount of sclerosis. *D*, decay; *S*, *S*, sclerosed areas.

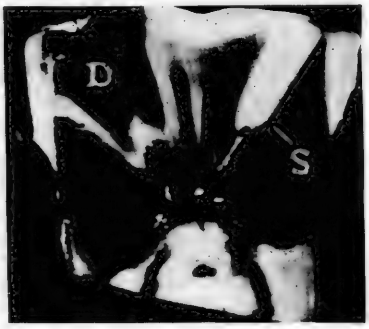

FIG. 4. Small cavity, *D*, with sclerosed zone between decay and the pulp. *S*, sclerosis under abrasion.

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rosed tooth crown (*fig. 1*). The almost universal occurrence of teeth in various stages of modification has now been established. In my first paper the term "sclerosis" was adapted with some misgivings;[3] its general use indicates that it has become acceptable.

In this work, the tissues of teeth that had succumbed to caries usually displayed, as judged by their reaction to stains, a loose molecular structure. Contrary to the behavior of intact teeth from mature individuals, dentin shows diffuse staining. These teeth appear to have lost the power or, for other reasons fail, to develop the hypercalcified sclerosed dentin commonly found in intact adult teeth. After preliminary experiments, I tested 110 carious teeth with pulpal involvement. The clinical history of these teeth is unknown. The large size and condition of the cavities suggest that pain led to the extractions. The teeth were collected in jars containing formalin solution; halved longitudinally; washed for twenty four hours; and finally subjected to the routine staining method. The results, when compared with those of similar experiments on intact teeth, justify significant deductions.

In a paper read before this Association in 1931, a report on similar treatment of 70 intact teeth was made.[4] Of this lot 38 percent exhibited sclerosis of over one-half of the anatomical crown; 35 percent displayed sclerosis over one-fourth to one-half of the anatomical crown; another group containing 18 percent of the 70 teeth showed minimal amounts of sclerosis. Together the total number with sclerosis amounted approximately to 92 percent. Important for comparison with the work reported below is the number of teeth that completely lacked evidence of sclerosis, i.e., 8 percent of the total number.

In the carious teeth in the present test, a different picture is unfolded. The percentage of teeth with sclerosis, as measured by the standards used in the foregoing experiment with intact teeth, is here reduced from 92 percent to 16 percent; the number devoid of this modification of the dentin is raised from 8 percent to 85 percent. The great differences between the percentages in this test, and those of the

[3] Beust: Reactions of the dentinal tubules to external irritation. *Jour. of Amer. Den. Assoc.*, June, 1931; p. 1060.

[4] Beust: Resistance to caries. *Jour. of Den. Research*, Aug., 1931; p. 619.

former experiment, are further emphasized by the minimum amount of reaction tissue in teeth designated as sclerosed. In no tooth does the chromophobic tissue exceed in quantity the sclerosis shown in the group with the least sclerosis reported in the first experiment. *Fig. 2* illustrates a decayed tooth utterly lacking in sclerosis. *Fig. 3* may be accepted as an average example of teeth designated as sclerosed in the experiment with carious teeth. Surprising and significant is the total absence of the transparent zone. *Fig. 4* suggests how this zone commonly appears in halved teeth. This resistance zone is found under practically all cases of slowly developing caries.

This report confirms the prediction made when the first experiment was published in 1931; namely, that "sclerosis is an expression of factors of resistance (to decay) possessed by a tooth," and that "a tooth's resistance to caries or other tooth-destroying agents increases in proportion to the amount of its sclerosis." Time has permitted only a brief and superficial report. Another, to follow shortly, will include remarks on cavities appearing below the enamel line, late in life. Notwithstanding the divergent views on caries etiology, bacteriologists, dietitians, and sialologists must henceforth consider the relation between sclerosis, or the factors causing sclerosis, and caries immunity, which a close study of these experiments will reveal.

BACTERIOLOGICAL, CHEMICAL, AND NUTRITIONAL STUDIES OF DENTAL CARIES BY THE MICHIGAN RESEARCH GROUP[1]

A Summary

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The investigations which have been carried on by the Michigan group during the past four years, in the study of dental caries, have been directed along three general lines: bacteriology and immunology, chemistry of blood and saliva, and nutrition. Each project has been reported in detail in special communications, which have already been published or are in press. Since these reports are appearing in a variety of professional journals—dental, bacteriological, chemical, and nutritional—it has seemed desirable to prepare a brief summary of the entire group of publications for the convenience of those who are interested in the study of the whole problem.

Bacteriologic studies. Jay et al. (1), in a comprehensive review of their studies on the bacteriology of dental caries, reaffirm the statement they and others made previously that a close correlation exists between the activity of B. acidophilus in the mouth and dental caries. They state that when growth of this organism is consistently prolific in the mouth, caries invariably follows; and that when there is no dental disease, B. acidophilus is either consistently absent from the mouth and intestinal tract, or is present only in small numbers, or appears intermittently. They were unable to implant human strains of B. acidophilus in the mouths of caries-free rats, or in the mouths or intestinal tracts of humans who were immune to dental caries. A group of caries-free children were fed a pint of acidophilus milk daily

[1] Researches conducted in the School of Dentistry of the University of Michigan, under the auspices of the Children's Fund of Michigan. Presented at the twelfth general meeting of the International Association for Dental Research, Chicago, Ill. March 18–19, 1934.

over a period of one week. At the end of this period the organism could not be recovered from the mouth, but was present in the intestinal tract. Two weeks later cultures of the stools were also negative. These observations strongly suggest the existence of an immunologic influence against the growth of B. acidophilus in caries-free individuals. In a study of the immunologic factors involved, the presence of agglutinins against B. acidophilus was demonstrated in the blood serum of caries-free patients. Furthermore, these investigators were able to raise the B. acidophilus agglutinin titre of blood-serum from caries-susceptible patients by injection of vaccine containing B. acidophilus. In skin tests, made by intradermal injection of B. acidophilus filtrates, it was found that many caries-susceptible individuals gave a positive reaction, while the caries-free were usually negative (2). Although the correlation of these tests to caries susceptibility was not 100 percent, the frequency of correspondence strongly indicates that some relationship exists. These findings substantiate the view that dental caries is a specific bacterial disease, and indicate the existence of controlling immunologic factors which might constitute a means of preventing the disease.

Intensive studies of the typal forms of oral and intestinal B. acidophilus have been made by Faith Hadley, et al. (3, 4), in which they have found that no consistent differences exist between the oral and intestinal strains. They have shown close correlation of this organism in the mouth to the activity of dental caries, and have determined the frequency of occurrence of various types of B. acidophilus under different degrees of caries susceptibility.

A valuable aid in the study of the bacteriology of dental caries was furnished by Faith Hadley (5) in the development of a method for quantitative estimation of B. acidophilus in saliva. Although this method does not give results that are as uniform as might be desired, owing largely to difficulties in obtaining uniform samples from the mouth, it does afford a useful selective method to cultivate B. acidophilus. Very illuminating data on the activity of this organism in the mouth, and its relationship to degree of caries activity, have been revealed by its use. In cases in which B. acidophilus was shown by the qualitative test to be present in caries-immune mouths, almost invariably the quantitative method indicated that the number of these

organisms was so small as to be insignificant, and that their presence was not constant. In a study of fourteen caries-susceptible children it was found that quantitative estimations of B. acidophilus in saliva, made over a period of several months, ranged from a few hundred to 500,000 per cc.; average, 60,000. A similar study of ten caries-free children showed that many of them were negative to B. acidophilus, and that in 81 percent of cases the B. acidophilus count was less than 100 per cc. of saliva. A few counts ranged higher. In a Negress, the count rose to a maximum of 19,200, but this was transitory and later dropped to zero. The average of sixty-nine examinations, including the exceptionally high counts, was 600.

These data confirm the view that dental caries is a bacteriologic disease, and that B. acidophilus is the most important specific etiologic factor. The growth of this organism in the mouth, and the degree of its caries-producing activity, are determined by certain underlying conditions of natural bacterial immunity and by dietary considerations which at the present time are not fully understood.

Chemical studies. Intensive studies have been made of chemical constituents of saliva and blood-serum as they relate to caries susceptibility. Hubbell has reported (6) data obtained from an 18-months study of saliva of 102 public school children, ranging in ages from 7 to 16 years. In these studies no relationship could be found between the calcium (Ca) and phosphorus (P) content of saliva and the occurrence of dental caries. To a group of these children one quart of milk and two ounces of tomato juice were given daily for eleven months; some also received viosterol. Although a slight decrease was noted in the frequency of dental caries among those receiving these dietary supplements, there was no consistent change in salivary Ca or P.

Analyses were also made by Hubbell (7) of saliva and blood serum from fifteen public-school children who were free from caries, and seventeen who had active caries. These children ranged in age from 9 to 16 years. Salivary analyses, made over a period of eighteen months, included estimations of total solids and ash; also Ca, P, Cl, diastatic activity, pH, CO_2-capacity, and total alkalinity. There were no consistent differences between the two groups in the amounts of these constituents, with two possible exceptions. It was found

that the average salivary CO_2-capacity of caries-free children was about 44 percent higher than that of children of the same age who had active caries. The values obtained from many individuals in both groups, however, varied widely from the averages. The average titratable alkalinity of saliva from the caries-free children was 24 percent higher than that for the caries-susceptible group. Individual exceptions to this rule also occurred in both groups. These differences were not found in the blood serum.

In a study by Koehne (10), in which a group of children whose quantitative food-intake over a period of months was satisfactory nutritionally, it was found that no constant correlation existed between alkalinity of saliva and either acid-base value of the diet or activity of dental caries. She found that alkalinity of saliva was not raised by increasing the amount of basic constituents of the diet, and that in caries-arrested children saliva was not consistently higher in CO_2-capacity. It is, therefore, the opinion of the group that freedom from dental caries is not related to increased alkalinity of saliva.

Hubbell and Koehne (8) made N, Ca, and P balance determinations on seventeen children, 7 to 11 years old, covering 35 *week*-collections. The only variable was the amount of sugar eaten. In those having from 1 to 11 percent of the caloric intake in the form of sugar, no change was noted in the retention of these elements; but in those who received 18 percent additional calories in the form of sugar, there were notable increases in retention of N and P; Ca retention was decreased in five out of seven cases. In cases showing evident arrest of dental caries, there was no such change in Ca and P retention as has recently been reported by Boyd and Drain (9).

The chemical studies by this group on saliva and blood from caries-free and caries-susceptible individuals, therefore, do not support claims made by others that the occurrence or degree of activity of dental caries is related to Ca, P, or acid-neutralizing values of either blood or saliva. No chemical differences were found in any other blood or salivary constituents which could be related to dental disease.

Nutritional studies. Studies of nutrition in relation to dental caries, conducted by Koehne and Morrell, were confined to three projects: (1) dietary supervision of 23 children in the University Hospital, Ann

Arbor, Michigan; (2) dietary study of 169 children in an orphan asylum; and (3) study of food habits of 9 caries-free and 9 caries-susceptible public-school children. These studies have been continued over periods of one to three years.

The study of the hospital group (10) was made on 23 metabolically normal girls from 6 to 13 years of age, all of whom were placed on a basal diet that was adequate nutritionally. Some were continued on this diet throughout the period of observation. Others were given, also, 100 grams of sugar daily in the form of candy. Some were given candy before meals; others, after meals. There was considerable variation in the food regimen, and the children were afforded freedom of choice in extra helpings of available foods. All foods, eaten, were weighed and recorded. Neither cod-liver oil nor sun-lamp treatment was given. Observation periods ranged from 5 to 18 months. As reported by Koehne and Morrell (11), intake of the various types of foods was remarkably constant for each child, regardless of the amount of candy eaten. Any change, therefore, which occurred in caries activity in these children while on this diet could not be related to differences in Ca, P, or vitamin intake, for these were constant. Of the 14 children continuously on the basal diet, or on this diet plus a moderate amount of sugar, 9 showed evidence of arrested caries; 5 had very little caries. Arrest of caries was associated with disappearance, or a very low count, of B. acidophilus in the saliva, while the counts remained high in the 5 cases showing continued caries activity. Among the 13 children on the basal diet plus a high sugar content, 9 had active and extensive caries. They also showed marked increase in the B. acidophilus content of the saliva. Three of the remaining children were true caries-immunes. There was no apparent difference between those who ate candy before meals and those who ate it after meals. When a diabetic diet was fed to a highly susceptible individual having a high B. acidophilus count, there was marked reduction of these organisms, approaching or reaching zero within a few days. In none of these cases was any change noted in salivary Ca, P, or acid-neutralizing power which could be related to the changed caries susceptibility. There was, however, an 88.9 percent correlation between activity of B. acidophilus in the saliva and dental findings for the whole group.

In the study of the orphanage group, as reported by Koehne (12), 169 children were observed over periods of from one to four and one-half years. This group was selected because all children in this institution, numbering about 300, had been examined by members of the Research Group at least once a year during the preceding six years, and found to have a remarkably low degree of caries. From 75 to 80 percent were entirely caries-free, and only 5 to 6 percent had an appreciable amount of dental disease. A study of the dietary conditions of these children was, therefore, undertaken to determine whether any apparent nutritional factor could be related to the freedom from caries. It was found that the diet, which had been fairly uniform throughout the period of observation, did not meet standard requirements for adequate nutrition. It was below the minimum standard requirement for calories in each age-group, and also inadequate in Ca, P, and vitamin-D contents. It contained little milk and no butter. A small amount of meat was served daily. No oranges were available except at Christmas, but various vegetables were provided throughout the year, many of which were fed raw. Dessert consisted mostly of raw apple. Cookies and sweet dessert were fed only on Sunday. Of the total caloric intake, 40 to 45 percent was in the form of starch and cereals. No candy was allowed at any time. Only minimum amounts of sugar were used to sweeten foods, and no sugar was placed on the table. Certainly the freedom from caries among these children could not be attributed to adequacy of diet, nor correlated with any consistent increase in CO_2-content of saliva, nor to intake of Ca, P, or vitamin D. There was, however, an 88 percent correlation with the B. acidophilus content of saliva. No conclusions could be drawn from these studies relative to influence of nutrition on the freedom from dental caries among these children. Only three principles were noted that might possibly have a bearing: (1) low sugar content; (2) uniformity and regularity of diet; and (3) hard fibrous raw-fruit eaten at the end of meals.

In the third nutritional study, reported by Koehne (13), an analysis was made of food habits and dietary intake of 9 caries-free and 9 caries-susceptible children in public schools. These children were selected as the most typical cases obtainable in the two groups. Certain distinctive differences were found. Almost without excep-

tion those in the *caries-free* group had excellent appetites, and were not notional in food selections; as a rule, their meals were regular and uniform in character; one could take no milk because of allergy; they ate candy and simple desserts occasionally, but had no craving for sweets. The *caries-susceptible* group were decidedly notional in their food preferences, and did not select uniform or balanced rations; 3 had little milk—2 had one quart per day; practically all craved sweets, and ate considerable quantities of candy and highly sweetened foods. The chemical findings are included in the report of Hubbell (7) in which it is stated that no consistent difference could be found in either saliva or blood from the two types of individuals. A very clear correlation between salivary content of B. acidophilus and caries-susceptibility was shown by Hadley (5).

In view of many current statements relative to the importance of various food elements as protectives against dental caries, the results of the nutritional studies were most interesting. The fact that dental caries was completely arrested in a large majority who received, over a long period of time, a diet that was low in Ca, low in P, low in vitamin D, and also low in sugar, does not coincide with many present-day theories regarding dietary control of dental disease. Furthermore, the production of caries by addition of a considerable quantity of candy to the diet of individuals known to be receiving an adequate balanced ration is very suggestive. The manner or extent in which sugar enters the problem of dental caries is not as yet apparent. It was found that, in a majority, adequate well-balanced diet, low in sugar, was followed by arrest of active caries, but that no single dietary principle applies equally to all persons.

During the course of this study it became very evident that heredity or individual characteristics may definitely determine caries susceptibility, irrespective of diet. Some caries-free individuals could eat any food, and any quantity of sugar, without resultant increase in dental caries or in B. acidophilus in the mouth. In others who were caries-susceptibles, the disease could not be checked by adherence to any ordinary satisfactory diet. A diet low in both starch and sugar invariably produced marked and rapid decrease in B. acidophilus in the mouth. The number of individuals showing this inherent tendency to caries immunity or high susceptibility was small.

In a great majority, B. acidophilus and dental caries were definitely changed by regulation of diet. These inherent tendencies of individuals should be taken into account in evaluating effects of any dietary program.

Summary. The findings of the Michigan Group on dental caries may be summarized as follows:

1. No consistent correlation could be found between amounts of salivary total solids, ash, Ca, P, Cl, diastatic activity, pH, CO_2-capacity, or total alkalinity, and activity of dental caries.

2. No relationship could be found between intake of Ca, P, and vitamin D, or acid-base dietary values, and activity of dental caries.

3. Evidence is submitted indicating that sugar is a very important consideration in dental caries.

4. A remarkably low degree of dental caries was observed in children on a low-sugar diet deficient in Ca, P, and vitamin D.

5. By increasing sugar intake, active dental caries was induced in children while they were receiving a diet that was nutritionally adequate.

6. Ingestion of low-sugar diets was conducive to freedom from dental caries in a majority of individuals.

7. The most constant differential between caries-free and caries-susceptible individuals is that of relative number of B. acidophilus organisms in the mouth. This correlation was approximately 90 percent positive.

8. There is a possible immunologic factor antagonistic to B. acidophilus in the blood of caries-free individuals, in whose mouths, as a rule, B. acidophilus does not exist; and when planted therein, promptly disappears.

9. The possibility of increasing immunity against B. acidophilus in caries-susceptible individuals by vaccine therapy is suggested.

10. Inherited tendencies or inherent individual characteristics were, in a small percentage of cases, more important determinant factors in caries susceptibility than ordinary dietary conditions. A great majority of caries-susceptible individuals, however, can apparently be benefited by simple dietary measures.

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FORCES EXERTED ON THE HUMAN MANDIBLE BY THE MUSCLES OF OCCLUSION[1]

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By attention to details of technique the art of dentistry has reached a high degree of efficiency. On the scientific side, there is increasing demand for detailed knowledge of anatomical and physiological facts that form the basis of its practical achievements. The investigations herein recorded are an attempt to augment that type of knowledge, made at the request of Dr. S. G. Ritchie, Professor of Dental Anatomy and Prosthetic Dentistry in Dalhousie University, who pointed out the lack of information concerning the forces exerted by the individual muscles of occlusion and their lines of action.

PREVIOUS INFORMATION

Measurements on cadavera. The force of a striated muscle is directly proportional to the area of its physiological cross-section, i.e., the section at right angles to all its fibers (Weber, Fick, '10, Bryce). Weber (quoted from Fick, '11, p. 29) estimated that the cross-sections of the muscles of occlusion, for one side, were: *masseter*, 7.5 sq. cm.; *internal pterygoid*, 4 sq. cm.; *temporal*, 8 sq. cm. Weber stated that the cross-section of muscles could not be directly determined, and therefore employed a formula involving length and volume (the latter being obtained from weight of muscle and specific gravity of muscle substance). It should especially be noted that, apart from weaknesses inherent in the indirect method, Weber's work dated from before the time when it was realized that the variation is as important as the average. In such determinations Weber took the average of a few specimens, e.g., of two cadavera in his estimates of the forces exerted by the muscles of the human calf (p. 88), although there was

[1] A preliminary report formed part of the work for which the Ross Stewart Smith Prize was awarded to one of the authors (J. E. H.) by the Medical Faculty of Dalhousie University. Presented at the annual meeting of the American Association of Anatomists, April, 1933; and at the general meeting of the International Association for Dental Research, March, 1933: *Journal of Dental Research*, 1933, *13*, p. 243; June.

considerable variation between the two. Fick quotes Weber's figures on the jaw muscles as authoritative. Worthmann uses Fick's quotation in an attempt to show how the forces of these muscles are distributed between jaw-joint and molar teeth. Worthmann's article is of interest because its ground is somewhat similar to that covered by part of the present investigations. It differs from these, however, in various ways: forces are quoted from Fick, not determined afresh, and not applied to any special skull of known dimensions; possible variations are not considered; forces of the different muscles are not combined; and the resolution of forces is into planes different from those used in the present work.

Weber's method of area estimation has been superseded by direct measurement (e.g., Hermann). Gysi traced, on squared paper, outlines of cross-sections of the muscles of occlusion from two heads, obtaining the following average results: *masseter*, 3.87 sq. cm.; *internal pterygoid*, 2.3 sq. cm.; *temporal*, 4.3 sq. cm. It is not stated whether these are averages for muscles from both sides, nor is any indication of variation given. For the immediate purpose for which Gysi required the information, such a result was probably adequate; but the difference between this estimate and that of Weber is sufficient to show need for further investigation before the values can be applied in dentistry.

If muscles are to be merely compared with one another in respect of force, the areas themselves are sufficient to convey a fairly accurate idea of relative force, although there is variation from muscle to muscle in the force exerted per sq. cm. If, however, absolute forces are required, the transformation must be made on the assumption that each sq. cm. of cross-section exerts a certain force. This force has been variously estimated (Bryce, p. 5; Fick, '10, p. 296) as 7.2 kg. (Haughton), 8.7 kg. (Henke) and, more recently, 10 kg. (Johnsson). The last-mentioned value was arrived at (du Bois-Reymond) by testing the elbow flexors of a large number of Finnish soldiers. Although this appears to be the only information available, Fick ('10), probably the chief modern authority on muscle and joint mechanics, accepts 10 kg. per sq. cm. as the most reasonably close approximation; but points out that variations probably result from different textures of muscle, and therefore occur in different parts, and between one person and another. On that basis, the total force exerted by the three pairs of occlusive muscles would be about 400 kg. (on Weber's value), or 210 kg. (on Gysi's value).

Determinations of force on the living subject. The gnathodynamometer consists of a spring, a dial or scale to register pounds of pressure, and two rubber pads, on which the subject bites. This instrument has been exten-

sively used to register biting force; and, placed usually between the molar teeth, gives, even in the adult, great variations of force from one individual to another. Some results are quoted below, where they can be conveniently compared with forces estimated in the present investigation. In making this comparison it has to be noted (1) that forces estimated from the cadaver are total forces, irrespective of direction, whereas biting force, registered by gnathodynamometer, is an upward force, and should therefore be smaller than the total. (2) Force on the cadaver is the maximum force exerted voluntarily, whereas biting force depends on the discomfort that may be produced (Black), and on the correctness of the occlusion (Johnson and Hatfield). The biting force would, therefore, be apt to be less even than the upward fraction of the total possible force. (3) One of the most important reasons for the present investigations is the fact that the gnathodynamometer does not distinguish between effects of different muscles.

SCHEME OF THE PRESENT INVESTIGATION

In no branch of medicine or surgery is there more need than in dentistry for appreciation of variation from person to person. The above-mentioned studies of individual muscles of occlusion revealed no attention to such variation. There has, also, been insufficient attention to the directions of forces of different muscles. In the present investigations we aimed to commence to supply these desiderata. The scheme may be summarized as follows: (1) Measurement of physiological cross-sections of three pairs of muscles in cadavera, to indicate relative forces exerted by each muscle. (2) Approximate determination of absolute force of each muscle by assuming unit force to be 10 kg. per sq. cm. of physiological cross-section. (3) Measurement of direction of force of each muscle, and resolution into forces upward, forward or backward, inward or outward. (4) Estimation of forces as referred to molar teeth. (5) Comparison of results with biting forces determined by gnathodynamometer. (6) Examination of relationship between forces determined on cadavera and such factors as age, sex, and dentition. We did not establish an accurate average-force applicable either to the living, or to any other series of cadavera. Not even the complete range of variation can be stated. On the other hand, the investigation can claim to show, even with the few specimens used, (a) the type of variation that may be expected, and, by comparison with results obtained on the living, (b) the degree of confidence that may be placed in such examinations of the dead.

MATERIAL AND METHODS

As a preliminary investigation, nine cadavera were examined while undergoing routine dissection. The ages varied from 22 years to 87. Five were females; four, males. The dentition ranged from completely edentulous to nearly all teeth present. Owing to frequent exposure during dissection, there was considerable drying in this set. For this reason, temporal muscles were not investigated, and areas of the other two pairs could not be used to give absolute forces. They were of use, however, as will be shown below, for other parts of the investigations. This set is referred to as the 1931–2 specimens. Another set of three cadavera (1932–3 specimens) was specially investigated, and kept moist to prevent error due to drying. It is on the results from these specimens that chief stress is laid in subsequent records. All specimens had been preserved by carbolic acid, formalin, methylated spirits and glycerin. Although Fick ('10, p. 295) considers that formalin preservation does not vitiate results, use of preserved specimens may be criticized; but, for comparison of areas of muscle sections from one muscle to another and from body to body, it was obvious that this preservation could have comparatively little detrimental effect. Judging by the general appearance of the three cadavera specially selected, it is improbable that much shrinkage had taken place, so that the absolute forces were probably not much different from those that might have been obtained with recent unpreserved material. The dentition was good in all three. Other data are shown in *table 1*.

In the first set of cadavera the muscles examined on each side were the masseter (superficial and deep parts) and internal pterygoid. With mouth closed, the line of action of each muscle was determined by marking mid-point of origin and mid-point of insertion (or, more easily, of a line across the muscle just above the insertion). The mid-points when joined gave a line which could be produced to meet the eye-ear plane (marked from lower margin of orbital opening to upper margin of external acoustic meatus). The angle thus formed (opening backward and downward) was measured with a transparent flexible protractor. It was judged sufficiently accurate and very convenient to mark the same points for the centers of insertion of superficial and deep parts of the masseter, and (on deep aspect of mandible) for the internal pterygoid insertion. In the second set of cadavera (1932–3 specimens), points of insertion of the superficial part of the masseter and internal pterygoid were taken at the angle of the jaw, while the center of insertion of the deep part of the masseter was marked at a point above and in front of the angle. This change was made because

it seemed to promise greater accuracy. The temporal muscle (completely examined only in 1932–3 specimens) was subdivided into anterior and posterior parts by a vertical line (i.e., perpendicular to eye-ear plane) drawn upward from the tip of the coronoid process. The coronoid tip was considered the center of insertion for each of the two portions; the center of origin of each was taken midway between upper and lower margins, and midway between front and back margins of the part under examination. These mid-points of origin were joined to the tip of the coronoid, and angles thus made with the horizontal (eye-ear plane) were measured. Exception may be taken to these methods of selection of

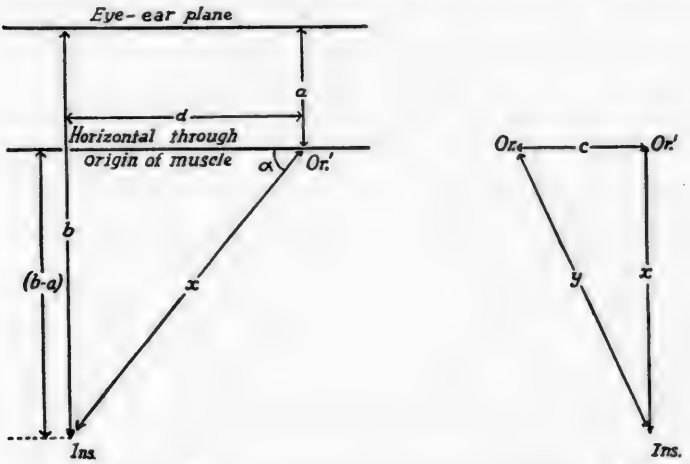

FIG. 1. DIAGRAM OF FORCES EXERTED BY MUSCLE OF OCCLUSION.
For explanation of lettering see text, pp. 111–12. *A*, side view; *B*, front view.

points, and it is proper to state that all were made after careful consideration and for definite reasons. In the second set of investigations, angle measurements were largely dispensed with by making an extra measurement—distance between center of origin and center of insertion.

Fig. 1 (A and B) illustrates the further measurements on various muscles and parts. The diagram fits best the masseter, but corresponding measurements were made also on other muscles. In the figure, a is the vertical distance between eye-ear plane and center of origin, *Or'*; b is the vertical distance between eye-ear plane and center of insertion, *Ins.*; therefore $(b - a)$ represents the vertical height of the muscle. The angle α is the

angle (on vertical antero-posterior plane) between the central fiber of the muscle and the eye-ear plane; x is the distance on the *vertical plane* between center of origin and center of insertion, and is found trigonometrically from measurements already enumerated. Now, the true central fiber of, say, the masseter passes laterally (outward) from insertion to origin, as represented in B, where x is, as before, the line passing upward and forward (say, toward the reader), while y is the true central fiber, passing upward, forward, and laterally from center of insertion to true center of origin, Or; while c is the lateral distance between these two centers. This distance was found by measuring with calipers across the skull, at centers of origin and of insertion, the corresponding muscles on both sides. Half the difference between transverse measurement at the origin and transverse measurement at the insertion gave the value of c. Examination of the two triangles shows that, if y be made to represent total force of the muscle or part under consideration, then, according to the method of rectangles and triangles of forces, c will represent the outward or inward component; $(b - a)$, the upward component; d, the forward component. For the masseter, c was an outward component; for the internal pterygoid, an inward component; for the anterior part of the temporal, an inward, and for the posterior part of the temporal, an outward component.

To obtain total force, a complete cut with sharp scalpel was made through each muscle or part of a muscle at right angles, as nearly as possible, to all fibers. This gave the physiological cross-section,[2] the area of which was found by inking upper and lower cut-surfaces, and impressing on a paper the surfaces wet with ink. This was done three times for each upper and lower cut-surface, giving six tracings for each (except in one or two muscles, where only three tracings were satisfactory). Thus far the method recommended by Fick ('10, p. 295) was followed. Areas were then found by retracing inked areas on kodaloid; cutting them out with sharp scalpel; weighing and applying, to the average of two sets of three weighings, the weight of a sq. cm. of kodaloid. The areas gave the relative force of the muscles, and Johnsson's estimate of 10 kg. per sq. cm. was used to give absolute force. By reference to the triangles of *fig. 1*, or to similar triangles for other muscles, the theorem of Pythagoras and trigonometrical functions

[2] It is disputed whether absolute muscle forces can be estimated with muscle at its greatest length, or midway between least and greatest lengths. Fick, in adopting the value 10 kg. per sq. cm., chose the second alternative. In such an examination as the present, there is no control over amount of contraction. Most mouths were more or less open, i.e., the muscles were between their greatest and least lengths. To determine direction of muscle pull, the mouth was forcibly closed.

permitted the resolution of total force into components—upward, forward or backward, outward or inward.

RESULTS

Magnitude and variation of different forces. *Table 1* gives details for the 1932–3 specimens because of our confidence in these results. Data for 1931–2 specimens are summarized here (*areas in sq. cm.*):

L. superf. masseter (9 muscles).—mean: 1.440; stand. dev'n: ±0.3308; stand. error: ±0.1103; approx. coeff't of var'n: 23 percent.
L. deep masseter (9 muscles).—mean: 0.976; stand. dev'n: ±0.2316; stand. error: ±0.0772; approx. coeff't of var'n: 23 percent.
R. superf. masseter (8 muscles).—mean: 1.594; stand. dev'n: ±0.2319; stand. error: ±0.0819; approx. coeff't of var'n: 15 percent.
R. deep masseter (9 muscles).—mean: 1.160; stand. dev'n: ±0.2854; stand. error: ±0.0951; approx. coeff't of var'n: 25 percent.
L. internal pterygoid (8 muscles).—mean: 1.719; stand. dev'n: ±0.2582; stand. error: ±0.0913; approx. coeff't of var'n: 15 percent.
R. internal pterygoid (7 muscles).—mean: 1.874; stand. dev'n: ±0.4071; stand. error: ±0.1538; approx. coeff't of var'n: 22 percent.

Coefficients of variation range from 15 to 25 percent. In the 1932–3 specimens (three heads), a similar or even greater range was suggested (10 to 30 percent). By the analysis-of-variance method (Fisher, p. 197), it was shown that total areas of muscles of right and left sides agreed more closely with each other than did those of the heads with each other. Data on which this calculation was made are appended:

Total cross-sectional areas (sq. cm.) of masseter and int. pterygoid (1931–2 specimens)

Cadaver no.....	I	II	III	IV	V	VI	VIII	IX	X
Left side.....	3.20	4.57	3.42	3.68	4.15	4.83	5.51	4.15	3.98
Right side.....	4.19	4.83	3.20	—	3.42	5.67	5.09	5.09	4.40

The statistical quantities derived from these data were: z: 0.7472; n_1: 8; n_2: 8. Fisher's tables show the "5 percent point" for these values of n as 0.6175.

For comparison with estimates of area quoted above from the works of Weber and Gysi, forces in *table 1* may be reconverted into sq. cms. by dividing by 10. It will then be seen that 1931–2 specimens give a lower average area than either of the quoted estimates; 1932–3

specimens occupy an intermediate position. The difference between the two sets was obviously attributable to drying of the 1931–2 specimens during the students' dissection, and therefore the absolute forces for this set have not been shown. There is, however, much more justification for the acceptance of relative values indicated by this set, for both sides of any given specimen were subjected to very much the same conditions of exposure to air, etc. There was a possibility that masseters, being more exposed, would show greater relative shrinkage than internal pterygoids. Comparison of the 1931–2 specimens with the second set supported this idea, but there was no proof of significant difference.

Component forces. For comparison of cadaver forces with gnathodynamometer forces, it was necessary to resolve total estimated forces into their components, and then convert these into forces acting, not at the point of insertion, but at the molar teeth. In the final stage of a bite, when the teeth are practically together, the mandible is often considered as a third-class lever, with its fulcrum at the center of the jaw-joint. Upon this assumption, by use of the method of moments, there were calculated the forces acting upward and forward at the middle of the upper surface of the mandibular second molar (*table 2*). Since the estimates were made for the second lower molars on each side, a combination of the totals of upward force (right and left) enables one to estimate the force exerted on either side (Gysi). These total upward forces were: Cadaver I—81.22 kg.; II—105.62 kg.; III—76.72 kg. From gnathodynamometer observations, Black (p. 161) gave 171 pounds (approximately 77.5 kg.) as the average force on the molars, determined in 1000 persons (his students, therefore, mostly young adults), the range being from 25 pounds to 275 (maximum capacity of the instrument). These figures were obtained from persons not specially selected, excepting to exclude those with teeth so carious as to be liable to damage by the experiment. Johnson and Hatfield showed that for boys of 16 to 18, with normal dentures, the average force on the first permanent molar is about 115 pounds, i.e., about 52 kg. Friel's figures, for children of 76-8 cm. sitting height (i.e., about 12 or 13 years), showed a force of roughly 120 pounds (about 54.5 kg.) on the first molar. It should

be noted that Friel found that forces on the second molar and second premolar were about 50 percent less than those on the first molar.

Further comparisons in detail are unnecessary. It is fairly clear that values obtained on cadavera of three individuals with good average dentitions are comparable with average figures obtained by Black. It might therefore be claimed that individual forces for different muscles have been fairly accurately calculated. The whole matter of final results is, however, very complicated, even apart from the fact that the estimate of 10 kg. per sq. cm. does not necessarily apply as properly to masticatory muscles as to elbow flexors, from which it was calculated. It must, in particular, be noted that the forward component of the force will, acting on the angled lever (the mandible), act as an upward force also, while the upward force is partly employed in keeping the mandibular head in its fossa. Rather than to discuss this leverage problem, it has been thought best to state forces and their distances[3] from the mandibular head and from the teeth (*table 3*), so that future investigation may have a starting-point of observation. The aim of this investigation was, partly, to obtain data that would contribute to the solution of the vexed problem of mandibular leverage. Only by some such data can that problem be solved.

Influence of sex, age and dentition. The specimens gave no indication of sex, or age, differences in total forces exerted by masseters and internal pterygoids, but in specimens from the first set (1931–2; nos. VI and VIII, both males) with better molar dentition than the rest, total forces, represented by area of physiological cross-section, were remarkably similar (10.5 and 10.6 sq. cm.); and, in both, greater than in any others of the series. Mean of the two specimens with good molar dentition—10.550 sq. cm.; mean of the seven specimens with poor molar dentition—8.031 sq. cm.; difference—2.519 sq. cm. Because the number of specimens was small, Fisher's *t* test (Fisher, p. 107) was applied. It showed that, if 100 such sets of specimens were taken, only one set might be expected to show so great a variation as a

[3] In obtaining data for *table 3*, the closest approximation seemed to be obtained by letting the antero-posterior measurements of superficial masseter, deep masseter, and pterygoid be the same. Temporal measurements were made independently, and indicate some discrepancy, owing, among other things, to unevenness of the bone in the region between coronoid tip and plane of the molars.

TABLE 1

Forces of muscles; 1932–3 specimens

CADAVER[1]			FORCES IN KILOGRAMS					
No. and muscle	Age	SIDE AND PART OF MUSCLE	Ant. or Post.	Lat. or Med.	Sup.	Resultant total	Combined totals: Parts	Combined totals: R. and L.
I: Masseter	67	L. Superf.	30.758	2.602	37.166	48.33	73.77	
		L. Deep	14.995	4.136	20.087	25.44		135.35
		R. Superf.	20.593	1.693	23.703	31.93	61.58	
		R. Deep	16.456	4.151	24.313	29.65		
Int. pterygoid		L.	7.987	10.984	21.404	25.35		52.37
		R.	14.961	11.707	19.212	27.02		
Temporal		L. Ant.	14.862	6.900	33.971	37.72	66.67	
		L. Post.	21.324	9.596	17.059	28.95		120.44
		R. Ant.	10.094	5.445	29.320	31.49	53.77	
		R. Post	14.850	6.289	15.374	22.28		
							Total of all muscles:	308.16
II: Masseter	26	L. Superf.	15.643	4.382	17.947	24.21	42.28	
		L. Deep	8.383	3.765	15.561	18.07		91.84
		R. Superf.	20.742	5.939	23.191	31.67	49.56	
		R. Deep	10.072	3.531	14.361	17.89		
Int. pterygoid		L.	21.629	8.577	27.087	30.70		80.52
		R.	22.130	14.341	42.267	49.82		
Temporal		L. Ant.	5.966	2.088	22.275	23.16	45.09	
		L. Post.	13.316	9.248	14.796	21.93		100.53
		R. Ant.	8.252	2.628	25.404	26.84	55.44	
		R. Post.	20.379	9.423	17.714	28.60		
							Total of all muscles:	272.89
III: Masseter	..[2]	L. Superf.	23.699	1.292	23.771	33.60	65.35	
		L. Deep	11.641	4.178	29.248	31.75		126.49
		R. Superf.	24.269	1.378	24.809	34.74	61.14	
		R. Deep	11.270	3.474	23.625	26.40		
Int. pterygoid		L.	21.115	14.109	19.048	31.75		60.61
		R.	18.677	13.743	17.179	28.86		
Temporal		L. Ant.	11.177	5.629	30.705	33.16	47.90	
		L. Post.	11.180	3.206	9.053	14.74		95.44
		R. Ant.	12.477	4.816	28.019	31.05	47.54	
		R. Post.	12.456	4.412	9.861	16.49		
							Total of all muscles:	282.54

[1] All males. *Causes of death:* I.—Valvular disease of heart. II.—Pulmonary tuberculosis; spontaneous pneumothorax. III.—Unknown.

[2] Age unknown: adult.

TABLE 2

Forces in reference to middle of upper surface of mandibular second molar (1932–3 specimens)

CADAVER NO.	MUSCLE	UPWARD FORCE (KG.)		FORWARD FORCE (KG.)	
		Left side	Right side	Left side	Right side
I	Masseter:				
	Superficial	9.66	5.55	51.00	33.11
	Deep	5.22	5.69	18.03	21.46
	Int. pterygoid	5.57	4.50	11.22	19.13
	Temporal	22.68	22.35	0.98	0.78
	Total	43.13	38.09	81.23	74.48
II	Masseter:				
	Superficial	8.13	7.44	24.47	30.59
	Deep	6.86	4.61	9.46	11.58
	Int. pterygoid	12.27	13.56	32.72	34.30
	Temporal	24.27	28.48	0	0
	Total	51.53	54.09	66.65	76.47
III	Masseter:				
	Superficial	6.71	5.43	34.26	31.01
	Deep	8.26	5.48	12.02	10.64
	Int. pterygoid	5.46	3.98	28.60	23.17
	Temporal	21.57	19.83	0	0
	Total	42.00	34.72	74.88	64.82

TABLE 3

Distances (cms.) on jaws of 1932–3 specimens. (For explanation of letters see fig. 2 and legend)

CADAVER: NO., SIDE, ETC.			MUSCLE	*b*	*x*	*y*	*d*
I	L	...	Superf. masseter	2.6	1.3	3.7	
		a: 3.95	Deep masseter	0.8	1.3	3.7	
		c: 1.0	Internal pterygoid	1.6	1.3	3.7	
		e: 4.7	Temporal	...	2.4	3.0	0.60
I	R	...	Superf. masseter	2.4	1.3	4.25	
		a: 3.95	Deep masseter	1.2	1.3	4.25	
		c: 1.1	Internal pterygoid	1.1	1.3	4.25	
		e: 4.5	Temporal	...	2.7	2.7	0.65
II	L	...	Superf. masseter	2.2	2.4	2.9	
		a: 3.9	Deep masseter	0.5	2.4	2.9	
		c: 1.0	Internal pterygoid	2.0	2.4	2.9	
		e: 4.5	Temporal	...	3.6	1.9	0.0
II	R	...	Superf. masseter	1.9	1.7	3.6	
		a: 4.0	Deep masseter	0.6	1.7	3.6	
		c: 1.0	Internal pterygoid	2.2	1.7	3.6	
		e: 4.5	Temporal	...	3.6	1.85	0.0
III	L	...	Superf. masseter	2.05	1.85	4.7	
		a: 4.6	Deep masseter	0.15	1.85	4.7	
		c: 1.1	Internal pterygoid	1.65	1.85	4.7	
		e: 4.0	Temporal	...	3.5	2.95	0.0
III	R	...	Superf. masseter	1.5	1.45	4.8	
		a: 5.4	Deep masseter	−0.3	1.45	4.8	
		c: 1.1	Internal pterygoid	1.3	1.45	4.8	
		e: 3.8	Temporal	...	3.35	3.05	0.0

result of chance alone. In other words, a definite influence produced differences between the two classes. The most notable other difference between them was, as already stated, the presence of better molar dentition in one pair than in the rest.

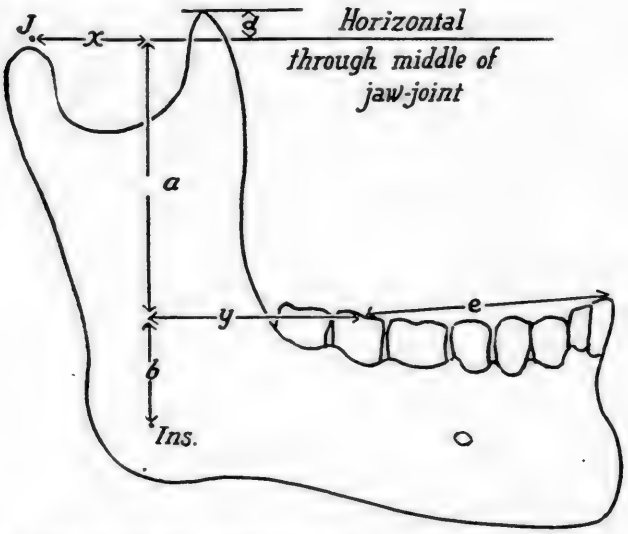

FIG. 2. DIAGRAM SHOWING DISTANCES TO BE USED IN TRANSFERRING FORCES TO VARIOUS POINTS ON MANDIBLE (TABLE 3).

a, Vertical from level of middle of jaw-joint to level of middle of upper surface of second molar. *b*, Vertical from level of middle of upper surface of second molar to insertion (*Ins.*) of muscle under examination. *c*, Distance from middle of upper surface of second molar to corresponding point on first molar (measurement not shown, but used in *table 3*). *d*, Vertical distance from level of middle of jaw-joint to tip of coronoid, for use in connection with temporal muscle only. *e*, Straight line from middle of upper surface of second molar to mid-point between upper edges of two central incisors. *x*, Horizontal from middle of jaw-joint to vertical drawn from insertion of muscle. *y*, Horizontal from middle of upper surface of second molar to vertical drawn from insertion of muscle.

Comparison of forces on right and left sides. For this purpose 1931–2 and 1932–3 specimens can be permissibly combined, specimens in which a muscle was abnormally dried being excluded. The results showed: Right masseter (superf. and deep, combined) greater than left in 8 specimens, left greater in 3; right internal pterygoid greater

than *left* in 7 specimens, left greater in 2. The χ^2 test showed that, when values of χ^2 derived from two sets of comparisons were combined, the result was not quite up to the conventional level of significance. The odds were not quite 20 to 1 against the arrangement being due to errors in sampling. Mean values (p.113) suggest, also, that right-side muscles were greater than those of the left; but here, again, differences are not great enough to take them quite out of the range of sampling errors. The relationship between dentition and force, and that between side of body and force, were placed before a meeting of the Halifax Section of the International Association for Dental Research. The ensuing discussion showed that clinical experience confirmed the first relationship; and that the second was highly probable because of the asymmetrical character of biting habits in many people. These views may be taken to justify confidence in the methods applied to the cadaver, even when the material, previously used for routine dissection, had become somewhat dried.

Comparison of muscles. In 1932–3 specimens, on the right side of cadaver II the internal pterygoid was so great that it was recorded as even a shade larger than the masseter on the same side (difference being within range of experimental error). With this exception, and after exclusion of a pair of muscles in which the masseter was abnormally dry and shrunken, the masseter was found to be greater than the internal pterygoid in all specimens on both sides (i.e., on 19 sides as against one side where pterygoid appeared a trifle larger). The ratio, $\frac{\text{area of cross-section of masseter}}{\text{area of cross-section of int. pterygoid}}$, varied from 1.00:1 (in specimen already mentioned) to 2.83:1 (on right side of no. X, 1931–2 specimens). The specimens afforded no evidence of significant correlation between size of masseters and size of pterygoids, nor between size of temporals and size of other muscles.

Amount and composition of forces at second molar tooth. Upward force: Total amount of upward force has already been commented on. It consisted of upward components of the masseter (superficial and deep parts), internal pterygoid, and temporal. *Table 2* shows that the temporal component was always at least half the total upward force; generally, just about half. Other muscles and parts varied much in regard to amounts they contributed. This was confirmed

by examination of 1931–2 specimens. *Forward force* i.e., the sum of forward components acting on the ramus of the mandible at the horizontal level of the upper border of the second molar, was, in each of three specimens, greater than the upward force acting at the second molar. The results were (1932–3 specimens): *Upward force* (kg.).—Cadaver I, 81.22; II, 105.62; III, 76.72. *Forward force*, (kg.).—Cadaver I, 155.72; II, 143.12; III, 139.70. As has been stated above (p. 115), it is foreign to the present purpose to discuss the ultimate directions and amounts of these forces when brought to bear on the angled lever—the mandible. It is important to notice chiefly that contributions of temporal muscles at this level are negligible. This is partly due to the fact that the tip of the coronoid process was in or near the horizontal plane of the mid-point of the jaw-joint. *Table 2* shows that the actual antero-posterior force of the temporal on the coronoid tip varied from about 12 kg. in a backward direction to a few grams in a forward direction. Again, relative parts played by the masseter varied much from specimen to specimen.

Inward and outward forces. In 1931–2 specimens, inward (medial) force of the internal pterygoid was greater than outward (lateral) force of the masseter, on both sides, except in one instance (i.e., in 8 bodies out of 9, or 16 sides out of 17, one internal pterygoid not being suitable for estimation). The exception was the one already referred to (no. X, right side), where ratio of masseter to internal pterygoid was very great—2.83:1. For this series, it might be suggested that the result arose from greater shrinkage of the masseter. In 1932–3 specimens, however, masseter force outward was always more than counterbalanced by inward pull of the pterygoid. Addition of the temporal component made, in these three specimens, a considerable difference, as shown below:

Cadaver no.	*Side*	*Force of masseter and pterygoid (kg.)*	*Force of all three muscles (kg.)*
I	L	4.246 inward	1.550 inward
	R	5.863 "	5.019 "
II	L	0.430 "	6.730 outward
	R	4.871 "	1.924 "
III	L	8.639 "	11.062 inward
	R	8.891 "	9.295 "

Owing to lateral projection of the temporal fossa at the origin of the posterior part of the temporal muscle, this part pulled outward, while the anterior part pulled inward. In Cadavera I and II, outward pull overcame inward, while in III inward pull was greater. In II outward pull of the temporal was sufficient, along with the masseter, to more than counterbalance inward pull of the internal pterygoid. Examination of details concerning this specimen showed that the difference was largely due to lateral prominence of the skull in the parietal region—the great interparietal breadth compared with that between the tips of the coronoid processes. The effect could not be claimed as due to greater relative power of the temporal muscle as a whole.

The conclusion of this section is an answer to one of the chief questions of this investigation. So far as can be shown, occlusive muscles, all exerting their maximum strength, may pull the jaw either medially or laterally. This pull is composed of an inward pull at or near the angle of the jaw, and a pull either inward or outward at the coronoid process. In spite of paucity of specimens, this conclusion was justifiable because the specimens were obviously sufficiently typical. Moreover, difference in actual amount of inward pull between I and III accords with the occurrence of outward pull in II. *General conclusion:* Direction of resultant pull depends largely on shape and size of skull, not only on size of muscles.

Direction of individual muscles. Since temporal muscles were thoroughly examined on three heads only, these comparisons were confined to masseter and internal pterygoid muscles. As already described, there was measured for each of these, on both sides of all twelve heads, the angle formed (in vertical antero-posterior plane) between central muscle-fibers and eye-ear plane—an angle open down and back. Main variations in different specimens are summarized here:

Deep masseter angles were greater than those of corresponding superficial masseter (on one side out of 24, the reverse was recorded). Pterygoid angle was greater than superficial masseter angle on 20 sides (from 12 heads). Pterygoid angle was equal to superficial masseter angle on two sides (2 heads), and less by one or two degrees than superficial masseter angle on two sides (2 heads). Deep masse-

ter angle was greater than pterygoid angle on 18 sides (10 heads), and less than pterygoid angle on 6 sides (4 heads). Superficial part of masseter forms smallest angle; deep masseter, the largest angle. Internal pterygoid forms angle intermediate between other two. This statement adds nothing to existent knowledge of these muscles. It appears to be important, however, that, when angles are actually measured, there are exceptions to the rule that cannot be accounted for entirely by imperfect closure of the mouth while observations were being made, for the sides of the same jaw frequently differed, as has been indicated. If allowance is made for experimental error, we see that the angles referred to, commonly considered to differ from each other, are not necessarily different; and there are indications that the usual size relation may even be reversed. There was no suggestion of correlation between angles formed by any two muscles—superficial masseter, deep masseter, internal pterygoid—nor between the internal pterygoid angle and the average angle formed by the two parts of the masseter combined.

Results suggested correlation between angles formed by corresponding muscles on opposite sides of any head; therefore, before mean values for different heads were calculated, means of the sides of each were taken. Mean values for twelve heads follow: *Superficial masseter.*—Mean: 51.917°; standard dev'n: ±4.824; standard error: ±1.39; coeff't of var'n: approx. 10 percent. *Deep masseter.*—Mean: 62.125°; standard dev'n: ±4.940; standard error: ±1.43; coeff't of var'n: approx. 8 percent. *Internal pterygoid.*—Mean: 58.292°; standard dev'n: ±6.247; standard error: ±1.80; coeff't of var'n: approx. 10 percent. The differences between superficial and deep masseters, and the superficial masseter and internal pterygoid, were obviously significant. The difference between deep masseter and internal pterygoid was not up to the conventional level of significance.

SUMMARY

Previous estimations of forces of occlusive muscles by examination of cadavera have been very scanty; results have not been concordant; and no attention has been paid to possible variation from one person to another. The object of the present investigations was to determine directions, relative amounts, and approximately absolute

amounts (possible variations, rather than averages) of forces exerted by the masseter (superficial and deep parts), internal pterygoid, and temporal (anterior and posterior parts).

Both sides of twelve heads of dissecting-room subjects were examined, ages being from 22 to 87 years, five specimens being females and seven males (temporal was measured on only three specimens). The method included determination of cross-sectional area, perpendicular to all muscle fibers, by inking cut surfaces, imprinting on paper, tracing on kodaloid, cutting out and weighing; estimation of absolute force on a basis of 10 kg. per sq. cm.; resolution of forces into components acting upward, forward or backward, laterally or medially. Total forces (both sides) in three heads completely examined were approximately 308 kg., 273 kg., and 283 kg.

By the method of moments, forces upward and forward were referred to the mandibular second molar. Upward forces at this tooth were comparable with certain gnathodynamometer results obtained from living persons. The forward component, there, exceeded the upward. Possible ultimate combinations of various forces were not analyzed, but tables are given to facilitate reference of forces to other points and combination of forces in other ways. Confidence in the method is strengthened by the agreement of certain results with clinical opinion; e.g., the greater average force associated with better molar dentition; and a tendency for right muscles to be stronger than left muscles. The direction, outward or inward, of the resultant transverse pull depended largely on skull shape.

In most specimens, angles between muscles and eye-ear plane were in the size-order: superficial masseter (least), internal pterygoid, deep masseter; but this relationship did not always hold, especially between pterygoid and deep masseter.

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POLYISOMERISM OF THE HUMAN DENTITION[1]

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Introduction. The word *polyisomerism* was recently introduced into the study of evolution by Dr. W. K. Gregory of the American Museum of Natural History. When applied to dental anatomy, the term denotes presence of similar parts, *isomeres*, in different teeth of the same dentition. The opposite condition, *anisomerism*, is one in which differentiation prevails. A striking example of anisomerism is found in the dentition of Smilodon, the sabre-tooth tiger. Polyisomerism may be general or intraregional: general, when all teeth of the dentition are alike, as in the dolphin; intraregional, when the teeth of a limited region are similar. Gregory (5, 6) has shown paleontological evidence of transition in the forms of many families, from primary polyisomerism to anisomerism (differentiation) and thence in some cases back to a state of secondary polyisomerism (de-differentiation). Recognition of this phylogenetic metamorphosis throws interesting light on interpretations of some evolutionary histories. The concept of polyisomerism is a timely supplement to recent investigations in experimental genetics and embryology on determining factors of evolution.

Heretofore, the human dentition has frequently been regarded as the most advanced morphological type at the recent end of an evolutionary chain. Study of the evolution of the teeth of man, with this notion as an axiom, has led to the conclusion that each detail of every tooth has some specific function. "I am firmly convinced," says Wheeler (13), "that there is a definite reason for every curve, angle and position of the human teeth." There are current beliefs among odontologists that certain grooves on the occlusal surfaces

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of posterior teeth are spillways which direct masticated food to buccal and lingual spaces. Shaw (10) maintains that the tubercle of Carabelli is being phylogenetically developed by 'Nature' in her attempt to increase biting surface of the molar tooth, and thus effect a more efficient chewing machine (*fig. 1*). Mother Nature, the guardian angel of the orthogenesis of the human dentition, is habitually invoked by dental anatomists in attempts to explain the origin of present human tooth-forms. Recent research in genetics indicates, however, that inevitable correlation between form and function is a myth. Because the teeth of man are no longer a decisive factor in evolution, this correlation can be supported only by Lamarckian principles. But the "new work in genetics has struck a fatal blow at the old doctrine of the inheritance of acquired characters" (Morgan, 9). Moreover, the direction of some evolutionary changes in the dental apparatus of man is not toward further differentiation but toward de-differentiation. The following discussion of polyisomerism of the human dentition deals with phylogenetic changes our teeth have undergone since they ceased to play an important rôle in evolution by selection. It is, in part, a record of biological decadence; perhaps the effect of aimless genic influences which, having pervaded the entire dentition, are leading it deeper into secondary polyisomerism.

Division of groups. Upper and lower dentitions are divided for convenience into four groups: incisors, cuspids, premolars, molars. The classification is based upon differentiation in ancestral forms where canines were large and prominent. Although differentiation is more marked in both ancient and modern anthropoids than in man, their dentitions are not strictly anisomeric, for there are similarities between premolars and molars. Distinctions among the groups of human teeth are less sharp because of general convergence of form. In each human jaw some characteristics are common to contiguous teeth in two adjoining groups; some are common to all teeth in two adjoining groups; some appear in every tooth. Then there are common characteristics of the members in corresponding groups of both jaws; finally, of dissimilar groups of both jaws.

Upper denture. The most striking polyisomeric phenomenon of man's dentition is the general tendency toward trilobulation of surfaces and cusps. It manifests itself on incisors, cuspids, and premo-

lars by division of labial surfaces into three well-defined lobes, and on all posterior teeth by division of each cusp into three lobules. In the former instance, Black (2) referred to the divisions as *developmental lobes*, naming them *mesial*, *central*, and *distal labial lobes* (*fig. 2*). Black probably used the word 'developmental' because of its implication of separate points of calcification, to which he refers in his text. At eruption, these lobes are accentuated at the incisal edges of incisors and cuspids, and at the edge of the buccal cusp of premolars. The lobes appear as three rounded eminences he called *mammelons*. When the teeth are fully erupted and begin to function, the mammelons are worn down to smooth edges. Both incisors and cuspids have an eminence on the lingual side of the crown near the neck of the tooth. Even before Black's time this was called *cingulum*, because of its supposed relationship to the cingulum of the primitive tooth. However, the connection between ancient and modern cingula is unsettled. In man the cingulum of the central incisor varies. It most frequently manifests itself as a smooth convexity of the cervical portion of the lingual surface, which throws forth two small lobules onto the concavity of the upper portion of the crown (*fig. 2*). The form of the cingulum of the lateral incisor is more variable than that of the central (*fig. 3*). The pattern just described—more primitive—appears only rarely on this tooth. Its most common form is a single convexity created by a swelling of the cervical part of the mesial marginal ridge. Sometimes a definite little cusp is present—a convergence toward the premolar pattern. The latter condition, with less frequency, also appears on the cuspid where the cingulum convexity is more pronounced.

The chief differences between central incisor and cuspid, as pointed out by Black (2), are the proportional sizes of the labial lobes. The central lobe develops to such an extent, on the cuspid, that it forms a prominence on labial and lingual surfaces. "The labial ridge occupies so much of the surface of the tooth that its margins are imperfectly defined. It belongs to the middle lobe, developed from the middle plate, which in the incisors is the smallest of the three, but in this tooth is much the largest" (Black, 2; p. 37—*fig. 4*). He also observed that "the bicuspids, though unlike the incisors and cuspids in the contour of their crowns, have the same number, and similar

distribution of primary parts, or lobes. They are, indeed, formed on the same general plan. The change of form is a result of a different relative development of the parts, by which the cingulum, or linguogingival ridge, is elevated into a powerful lingual cusp, which, in the upper bicuspids, is almost or quite as high as the buccal cusp." This observation is a landmark in dental anatomy and its importance is being more fully realized. Black, however, probably acquired this idea from Allen (1), who in 1874 taught that the cingula of incisors and cuspids became so enlarged in bicuspids as to give rise to the occlusal surfaces. Allen also maintained that upper molars represented a bicuspid whose posterior or distal side had budded off the whole distal half of the tooth, including the distolingual and distobuccal cusps.

The linkage of anteriors with posteriors, by a common basic design, is one of the important polyisomeric characteristics of the human dentition. The buccal or labial half of each premolar, like incisor and cuspid, consists of three primary parts, while the lingual consists of one. On premolars the large central labial lobe constitutes the crest of the buccal cusp. The lingual lobe is the lingual cusp, and the marginal ridges are analogous to marginal ridges of the cuspid and incisors. The occlusal surface of each premolar is surmounted by two cusp eminences, and the inner side of each cusp presents the trilobular pattern characteristic of teeth of man (*fig. 16*). The design of the three lobules of the lingual cusp differs from that of the buccal. In first and second premolars, lingual cusps look alike, but buccal cusps are dissimilar as to shapes and proportional sizes of the three lobules. On all cusps, however, the center lobule, or *triangular ridge* as Black called it, is the most prominent.

There are two types of furrows on the crowns. The first, a sharp line at the junction of primary parts, is V-shaped in cross-section. Black called it *developmental groove* (*fig. 5*). When, through lack of proper coalescence of primary parts, grooves are actually clefts in enamel, they are called *fissures.* The second type of furrow is the U-shaped groove that is not at the boundary of a separate lobe. Such a furrow is a *sulcus*, a term that differentiates it from *developmental groove.* It is important that this distinction be made, for evolutionary changes have affected the courses and number of developmental grooves, but have not influenced sulci.

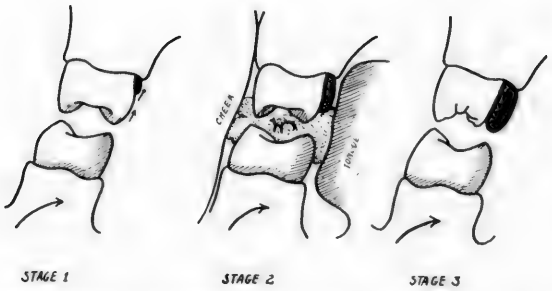

FIG. 1. Shaw's suggestion as to three structural stages in evolutionary development of fifth cusp. (After D. M. Shaw.)

FIG. 2. Diagrammatic illustration of labial and lingual aspects of common form of upper central incisor.

FIG. 3. Diagrammatic illustration of three variations of cingulum of lateral incisor.

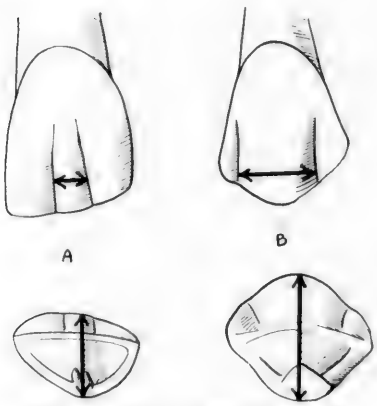

FIG. 4. Diagram of Black's observation on common structural plan of incisors and cuspid. *A*, central incisor. *B*, cuspid.

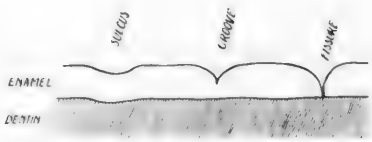

FIG. 5. Cross-section of enamel, showing differences between types of furrows.

Segmentation of the crowns of all teeth into a reduced number of lobes, separated by distinct lines of division, is another feature of intradental polyisomerism. The evolution of complex crown-forms

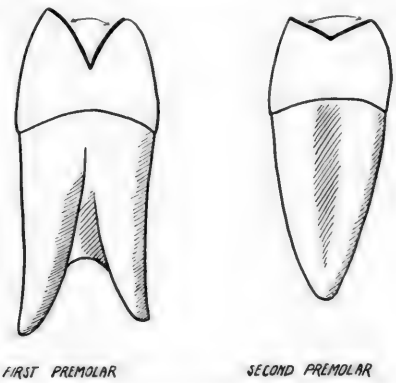

FIG. 6. Comparison of cusp depths and roots of upper first and second premolars.

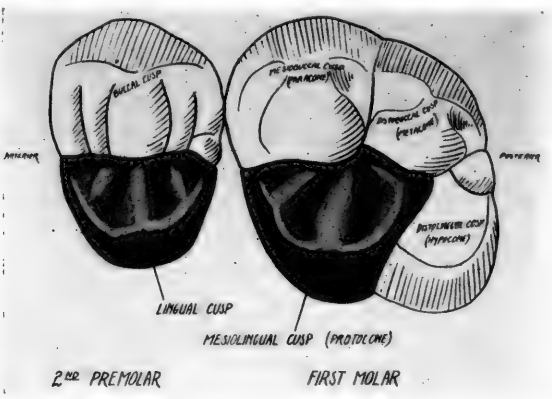

FIG. 7. Diagram illustrating analogy between lingual cusp of premolar and mesiobuccal cusp of molar.

from the concrescence of single cones has been a common but erroneous deduction from this phenomenon (3, 7). The four lobes of anteriors and premolars, and the four cusps of molars, have led many investigators to believe that all human crown-forms have been developed from four primary units. From the same fact, others have

inferred development of molars from premolars, premolars from cuspid, and cuspid from incisor. Reference to paleontological evidence, however, indicates that segmentation is a more recent acquisition; and that in general crown-forms are undergoing reduction in number of parts—and becoming simpler in general design, not more complex. Gregory (4) proved this to be the case in *lower* molars. Cusp-depth

FIG. 8. Photograph of upper dentition in which cingulum of lateral incisor is most pronounced of several polyisomeric features. (Courtesy of Dr. W. Baade.)

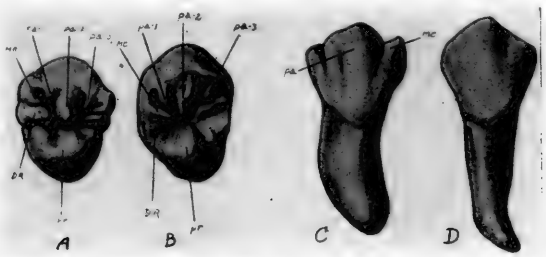

FIG. 9. Comparison of bicuspid-like upper third molar and second bicuspid. *A*, occlusal view of upper third molar. *B*, occlusal view of upper second bicuspid. *C*, buccal view of third molar. *D*, buccal view of bicuspid.

in the first premolar is greater than in the second; in this respect the second, with its shallow intercuspal space, resembles molars (*fig. 6*). Several parts of first molars bear striking resemblance to corresponding parts of premolars. The molar mesiolingual cusp is identical with the premolar lingual cusp (*fig. 7*). Both are divided into three similarly shaped lobules. The molar mesiobuccal cusp resembles the buccal cusp of the second premolar.

In each group that tooth which is most variable in pattern is also most variable in size. I have recently presented evidence for this

FIG. 10. Variations of same structural design in lower premolars. *A*, first premolar. *B* and *C*, second premolars.

FIG. 11. Radiograph showing bifurcation of root of lower second premolar. Splitting seems to follow plan of distribution of roots of adjoining first molar. (Courtesy of Dr. D. Ziskin.)

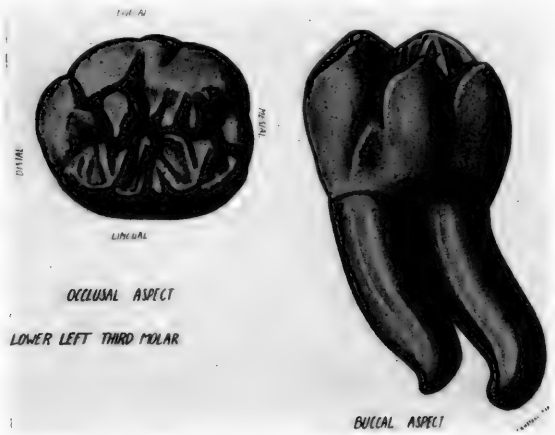

FIG. 12. Primitive type of human lower third molar closely resembling anthropoid pattern. Some cusps show more than three lobules.

in other papers (11, 12). Lateral incisor, second premolar, and third molar are most variable in the respective groups. The lateral incisor, despite its smaller size, is more apt to take on bicuspid features than either central or cuspid (*fig. 8*). The second premolar has more molar characteristics than the first; the third molar is

FIG. 13. Occlusal view of unerupted lower second molar of gorilla.

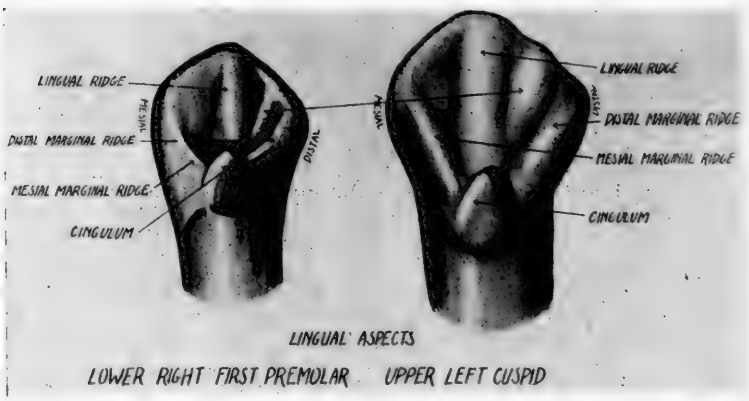

FIG. 14. Comparison of lower right first premolar and upper left cuspid; note marked similarity of corresponding parts.

more apt than other molars to have premolar features. In fact, many third molars so closely resemble second premolars that, were it not for differences in the roots, they could not be distinguished (*fig. 9*); with uncanny accuracy in detail, they are analogous cusp for cusp, ridge for ridge, groove for groove. The third molar is the most vari-

able tooth, and shows a great tendency to convergence toward the premolar pattern. In the fusion of roots is found further evidence of polyisomerism. Those teeth which show greatest convergence of form also show fusion of roots. Roots of the second premolar are usually shorter than those of the first, and are nearly always fused. Third-molar roots always show some degree of fusion, not infrequently

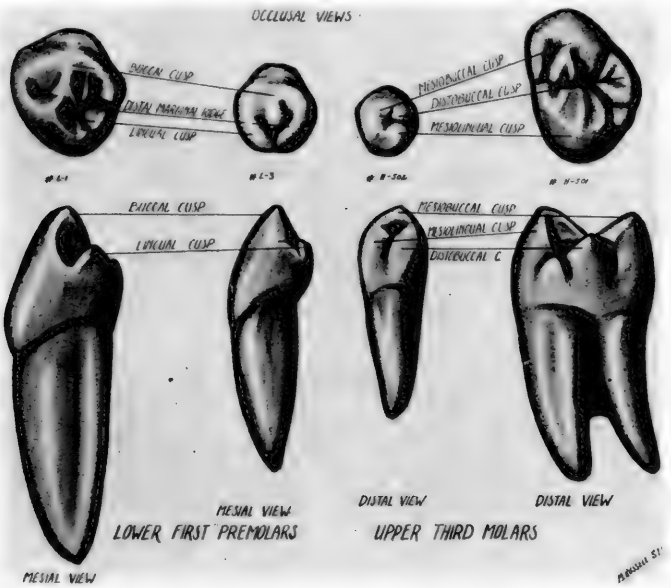

FIG. 15. Chart illustrating similarity between diminutive forms of upper third molar and lower first premolar.

being a single root which, on its sides, bears grooves indicating fusion of the three original prongs.

Lower dentition. In the lower dentition the differences between incisors are negligible (*fig. 16*). Laterals are slightly larger than centrals. There are no pronounced surface markings on either labial or lingual surfaces of these teeth, which are smoothly and evenly contoured, with little or no evidence of lobes save for mammelons on the incisal edges of unworn teeth. On the lingual surface of the cuspid, undulations in the enamel indicate rudimentary marginal ridges

and a cingulum, which is most pronounced on the cuspid. There is greater convergence of form between incisors and cuspid than between corresponding uppers (*fig. 16*).

The first premolar, on its occlusal surface, presents well-defined marginal ridges at mesial and distal borders. Central lobules of buccal and lingual cusps join to form one transverse ridge, which divides the occlusal surface into two fossae of unequal sizes (*fig. 10*). This asymmetry, an anatomical constant, is the pattern upon which

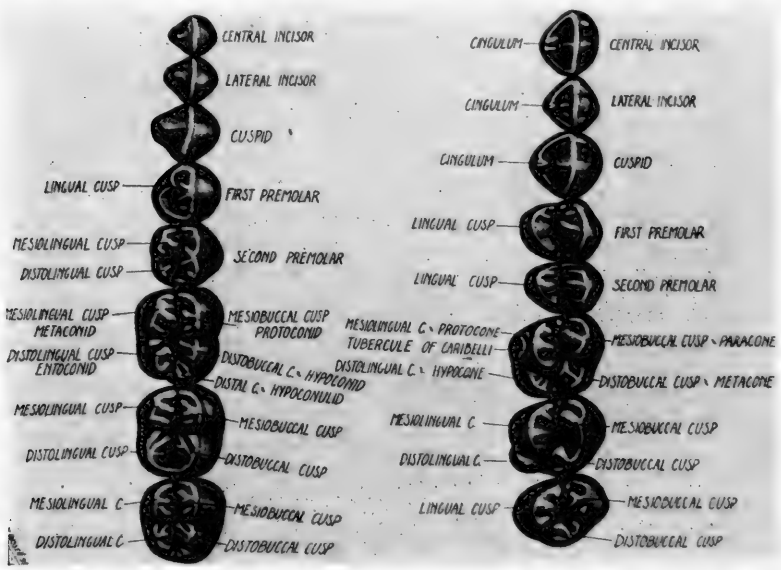

FIG. 16. Chart illustrating prevalence of trilobulation in human dentition.

variations of second premolars are designed. Even though the second premolar is regarded as a three-cusp tooth, it actually has the same basic form as the first. The distolingual cusp corresponds to an elevation on the distal marginal ridge. It appears in various sizes in different individuals. In the well developed three-cusp pattern, the lingual half resembles the lingual half of the first molar (*fig. 10*). The mesiolingual cusp is always the larger of the two lingual cusps; is more stable in form; and shows more distinct trilobulation on its occlusal portion. The distolingual cusp also shows this feature, but

more often presents a smooth surface. The buccal cusp of the second bicuspid is analogous to that of the first. Each premolar usually has a single root; the second sometimes shows a bifurcation into mesial and distal prongs like the first molar (*fig. 11*).

The five-cusp first molar is fairly constant in man. Each cusp, with different degrees of sharpness, shows trilobulation in the unworn state. Each cusp has its own variation in the arrangement and proportional masses of the lobules (*fig. 16*); the distolingual cusp alone is apt not to show this feature. Hellman (8) noted that "certain changes appear which tend to modify the fundamental pattern in the lower teeth of man by a gradual and progressive process of evolution." He traced the reduction of the five-cusp Dryopithecus pattern to the four-cusp form, and showed how different racial groups manifested molar forms at various stages of the transition. The third molar, like the upper, is very variable in both size and form. The five-cusp type is common. In this respect the crown resembles that of the first molar, but the ridges and cusp formations on the third are more primitive (*fig. 12*). Sometimes the number of lobules on each cusp is more than three. This is a distinctly anthropoid character (*fig. 13*), for in man there is a general tendency to reduction to three lobules on each cusp. Roots of the third molar show varying degrees of fusion. Although the third molar is the most variable tooth of the lower jaw, unlike the upper third, it does not appear in diminutive forms. It tends to larger types in its variations.

Upper and lower teeth. Besides the trilobulation of cusps, which is common to upper and lower teeth, the most outstanding linkage between the two dentures is the similarity between some of the variable forms of the lower first premolar and the upper cuspid, particularly with respect to an un-named additional lobe between central and distal lobes on lingual aspects (*fig. 14*). Some rudimentary forms of lower first premolars look like such forms of upper third molars (*fig. 15*).

Summary. By phylogenetic de-differentiation the teeth of man are undergoing convergence of form. Some teeth seem to be genetically more conservative than others. These are stable in size and form.

The most variable teeth of the *upper* denture are the lateral incisor,

second premolar, and third molar. All appear in diminutive forms; the lateral incisor and third molar are frequently absent. In the *lower* denture the second premolar and third molar are most variable. The changing tooth acquires characteristics of an adjacent differentiated group.

There is a general tendency for all cusps and labial surfaces of anteriors and premolars to acquire a trilobular pattern (*fig. 16*).

The teeth are phylogenetically being reduced to simpler basic patterns, and there is a strong tendency toward secondary polyisomerism.

I am indebted to Dr. W. K. Gregory, Curator of Comparative Anatomy at the American Museum of Natural History, for very valuable suggestions in the correlation of recent tooth anatomy with paleontological data; also for his assistance in the preparation of this manuscript. I am also grateful to Drs. D. Ziskin and W. Baade, of the College of Dental and Oral Surgery, for their coöperation in gathering material.

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EFFECTS OF FLUORINE UPON RATE OF ERUPTION OF RAT INCISORS, AND ITS CORRELATION WITH BONE DEVELOPMENT AND BODY GROWTH[1]

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This laboratory has been investigating effects of fluorine (F) upon composition of teeth, bones, and blood, and upon calcium (Ca) and phosphorus (P) metabolism of experimental animals (1, 2, 3). At the suggestion of Dr. Isaac Schour, who found that hypophysectomy decreased the eruption-rate of rat incisors (4), measurements of rates of eruption of incisor teeth of F-fed rats, as compared with eruption rates in control litter-mates, have been included in these studies. It is the purpose of this paper to report these findings, and to point out their relationship to bone development and body growth.

Experimental procedure. Albino rats, taken at the time of weaning (weighing from 55–65 grams), were placed upon experimental F-containing rations, while litter-mates were kept as controls upon the same basal ration *without addition of F.* The diets were those previously described (1). The basal diet consisted of two-thirds ground whole-wheat, one-third whole-milk powder, and NaCl equal to 2 percent of the weight of the wheat. NaF was added at levels of 0.05 and 0.1 percent of the ration. Food and distilled water were given without restriction of the quantities consumed.

At the beginning, when the animals were four weeks old, a horizontal mark was made with a very fine file at the gum line of the lower right incisor of each animal. A week later the distance between this mark and the gingival line was measured with an adjustable caliper (*table 1*). The distance between these two points represented the weekly rate of eruption. Each week the incisors in the normal animals were marked again in the same manner. As the rate of eruption

[1] Presented at the twelfth general meeting of the International Association for Dental Research, Chicago, Ill., March 17–18, 1934.

in the experimental animals was retarded, it was not necessary to mark their teeth so frequently. To facilitate location of the mark,

TABLE 1

Rates of eruption of the lower incisors of F-fed rats compared with control litter-mates

RAT NO.	RATE OF ERUPTION										TOTAL FOR 10 WEEKS
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	
Control group											
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
10361	4.7	3.9	3.1	2.9	2.9	3.0	2.9	2.8	2.6	2.5	31.3
10391	3.6	3.7	3.5	3.2	3.2	3.5	3.4	3.2	2.3	2.4	32.0
10393	3.8	3.8	3.5	2.7	2.9	3.0	3.0	3.0	2.7	2.8	31.2
10442	3.1	3.1	3.7	3.2	3.0	3.9	3.2	3.3	2.8	3.2	32.5
10447	3.7	3.1	2.7	2.9	3.0	4.3	3.2	2.9	3.2	3.2	32.2
10477	3.4	3.7	3.2	3.4	2.8	2.8	3.0	3.0	2.8	3.2	31.3
10478	3.2	3.8	3.4	3.3	3.8	2.8	2.7	2.9	3.1	2.8	31.8
10455	3.4	3.6	3.0	3.5	3.4	3.2	3.4	2.5	2.8	2.8	31.6
										Average	31.7
Group receiving food containing 0.05 percent of NaF											
10390	3.5	4.1	3.2	2.9	2.8	2.6	2.6	2.5	2.3	2.4	28.9
10443	3.3	2.9	3.2	2.5	2.7	2.2	2.7	2.6	2.2	2.9	27.2
10475	3.1	4.1	3.0	3.3	2.9	3.3	2.7	2.3	2.3	2.7	29.7
10476	3.5	3.5	3.2	2.7	2.7	2.5	2.5	2.5	2.8	2.3	28.2
10456	3.3	3.1	2.7	2.5	2.6	2.3	2.5	2.5	1.9	1.2	34.6
										Average	27.7
Group receiving food containing 0.1 percent of NaF											
10454	3.5	3.1	2.8	1.2	1.4	1.2	1.0	1.0	0.0	0.08	16.0
10457	3.6	2.9	2.1	1.8	0.6	2.0	0.3	0.6	0.4	0.08	14.5
10441	3.4	2.4	1.5	1.2	1.1	1.0	1.5	0.0	1.0	1.0	15.1
10445	3.1	2.9	1.6	1.6	1.1	1.8	0.9	0.0	0.5	0.5	14.0
10446	3.9	3.1	2.0	1.8	1.2	1.4	1.2	1.0	1.5	1.5	18.6
10472	3.1	3.0	2.2	1.1	2.3	1.8	2.0	2.1	1.1	1.1	20.3
10473	3.3	3.7	3.4	1.9	0.3	1.9	1.5	1.5	1.9	1.3	20.0
10474	3.3	3.5	1.1	2.2	1.1	0.5	1.2	1.2	1.0	1.5	16.6
										Average	16.8

ink was rubbed into the scratch, and a small hand lens was used. As the enamel chipped off the incisors of the F-fed rats in many cases, it was necessary to cut through enamel into dentine to avoid loss of

the mark. Only male rats were used, to exclude any variation in results which might be caused by sex differences in rate of eruption. Measurements, made over a period of ten weeks, on 21 animals representing 5 litters appear in *table 1*, where it may be seen that addition of F to the diet, in the concentrations indicated, caused marked inhibition in rate of eruption of the incisor teeth, after the first week. An average total growth (lower right incisors) of 31.7 mm. was recorded for the control rats; for rats receiving diets containing 0.05 and 0.1 percent of NaF, the growths were, respectively, 27.2 and 16.8

TABLE 2

Effects of F-feeding on growth of rats

PERCENTAGE OF Na F IN THE RATION	NUMBER OF RATS USED	AVERAGE 6-WEEK GAIN IN WEIGHT	AVERAGE GAIN PER GRAM OF FOOD CONSUMED
		grams	*grams*
0	40	158	0.339
0.05	20	133	0.295
0.10	20	63	0.199

TABLE 3

Effects of NaF upon retention of Ca and P by rats

RAT NO.	PERCENTAGE OF NaF IN THE RATION	TOTAL MG. OF Ca RETAINED PER GM. OF RAT	TOTAL MG. OF P RETAINED PER GM. OF RAT	C:P RATIO
9416	0.0	9.0400	8.6040	1.05
9414	0.05	7.7680	7.2584	1.07
9412	0.1	4.0016	4.1200	0.97

mm. Eruption rate decreased rapidly in the first four weeks, and then retardation proceeded more slowly—in some cases, in rats on diet containing the larger amount of NaF, it was nearly zero.

The enamel of the incisors of F-fed rats was chalky and corroded. There was also pronounced elongation of lower incisors in several animals, even though these teeth were growing only about half as fast as incisors of control rats. The observed tendency of F to cause overelongation of exposed portions of either upper or lower incisors is evidently not due to stimulation in rate of eruption, for the rate is diminished in F-fed animals. Decrease in eruption rate is propor-

tional to F concentration, though not arithmetically. When the ration included 0.05 percent of NaF, lower incisors erupted at about 87 percent of the rate recorded for controls; inclusion of 0.1 percent resulted in an eruption rate only 52.9 percent of normal.

An interesting analogy, which may throw some light on factors involved in tooth eruption, may be seen in effects of F upon body growth and bone development as measured by the ability of the rat to retain or store Ca and P. Data on effects of F-feeding upon growth are summarized in *table 2*. As before, the animals were given the experimental ration at the age of four weeks. Record was kept of their food consumption and weekly gains in weight during a 6-week experimental period. The data in this table show that F inhibited body growth and lowered food utilization. The retarding effect of F upon rate of body growth is approximately of the same order as upon rate of eruption of lower incisors. For example, as stated previously, when the ration contained 0.05 or 0.1 percent of NaF, incisors erupted, respectively, at approximately 87 and 53 percent of the normal rate. Inclusion of NaF in the ration of male rats, at these same levels, also resulted in a rate of body growth which was 84 and 40 percent, respectively, of that recorded for control litter mates. In other words, the retarding effect of F upon rate of eruption of incisors appears to run parallel with that of general growth.

Unpublished data accumulated in this laboratory have shown that F has no effect upon the ability of the rat body to utilize protein material. In all probability, therefore, the growth stunting effect of F is not due to any interference with the building of muscle tissue. A different picture is, however, presented when the effect of F upon the growth and calcification of bone is considered. Determination of the amounts of Ca and P retained or stored in the body of the growing animal is perhaps the best measure of bone development. The data in *table 3* were obtained by experimental determination of the balance between intake and output of Ca and P in the F-fed animals and their litter-mate controls. The rats were placed upon the experimental rations at the age of four weeks. Their food intake was recorded, and urine and feces collected quantitatively, for 40 days. Both food and excretory products were analysed for Ca and P, and the amounts of these elements retained by the animals

during this period calculated. The data reported here are a small part of a comprehensive investigation of effects of F upon metabolism of Ca and P in rats, dogs, and human beings, reported elsewhere (3). It is evident that NaF, when included in the ration at 0.05 and 0.1 percentage levels, decreased the ability of rats to retain the tooth- and bone-forming elements, Ca and P. Rat 9414, which received the ration containing 0.05 percent of NaF retained 85.9 percent of the Ca and 84.3 percent of the P retained by control Rat 9416 in the same length of time. Rat 9412, on a ration containing 0.1 percent of NaF,

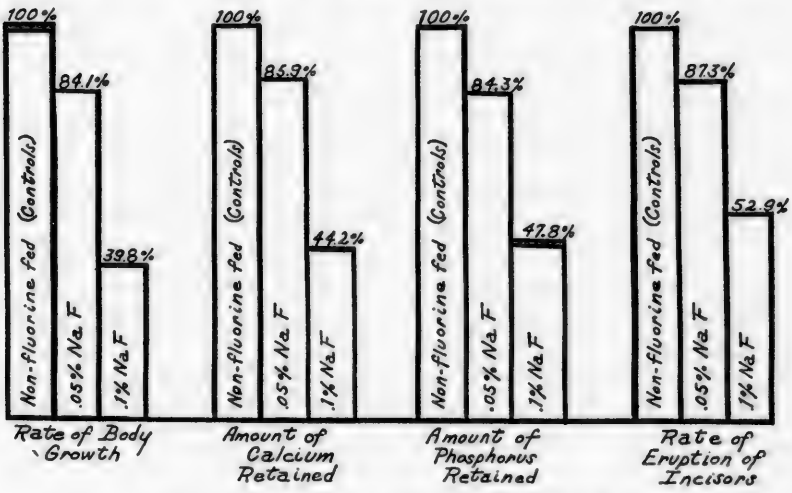

FIG. 1. GRAPHS SHOWING COMPARATIVE EFFECTS OF NaF

retained only 44.2 percent of the Ca and 47.8 percent of the P stored in the control animal. F-fed Rat 9412 was obviously growing muscle faster than bone, as shown by the lower Ca:P retention ratio. The decreases in Ca and P retentions in the F-fed animals parallel, and are of the same order as, the retardation in rates of body growth and eruption of lower incisors. The comparative effect of F upon these three physiological processes is shown graphically in *fig. 1.* It appears probable that the growth-stunting effect of F is a result of interference with metabolism of Ca and P, and thus with normal development of bony or skeletal tissues. This in turn may explain the

observed lowered eruption rate of incisor teeth, and suggests a possible factor in the normal process of tooth eruption.

Summary and conclusions. Rates of eruption of lower incisors of albino rats on rations containing 0.05 or 0.1 percent of NaF have been measured weekly over a 10-week period, and compared with eruption rates of litter-mate controls. When NaF is fed at these levels, rates of eruption of incisors were decreased. A total average eruption of 31.7 mm. during a 10-week period was recorded for control rats; for rats on rations containing 0.05 and 0.1 percent of NaF during the same length of time, the total eruptions were 27.7 and 16.8 mm., respectively.

NaF was also found to retard rate of body growth, and to lower retention of Ca and P. A probable relation between these three effects of NaF is suggested by similarity in the degrees of effects produced. When the ration contained 0.05 percent of NaF, rate of body growth, amounts of Ca and P retained, and rate of eruption of incisors, were (percent) 84.1, 85.9, 84.3, and 87.3, respectively, of that of control rats.

At a higher level of F- feeding (0.1 percent of NaF), the effect of F was more pronounced. These rats grew at only 39.8 percent of the normal rate; retained only 44.2 percent as much Ca and 47.8 percent as much P; and their incisors erupted at 52.9 percent of the rate recorded for control litter-mates. A possible relation of tooth eruption to growth and bone development is thus suggested.

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BIBLIOGRAPHIC METHODS IN DENTISTRY[1]

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"Research" is pronounced differently by different people: some say *re'search*, and others *research'*. This displacement of accent is significant, for all research consists of both varieties, and *re'search* comes before *research'*. By *re'search* I mean searching of literature; by *research'*, investigation of new phenomena. Dental research is primarily concerned about the latter type much to the neglect of the former. But the literary and experimental aspects of research are both indispensable and of equal importance, for no worker would embark upon any investigation without first reviewing and searching the literature upon the subject. In medicine and chemistry there are well established and standardized methods of bibliographic procedure that enable the investigator to locate quickly any desired information. In dentistry bibliographic tools are poor and scant, and apparently little or no attention is paid to their improvement. It is the purpose of this paper to point to grave defects in existing dental bibliographic aids, and to indicate desirable improvements. In the excellent and comprehensive study on "The Status of Dental Journalism in the United States," by the American College of Dentists,[2] there is a critical and sufficient discussion of the present type of dental periodical literature. Many of the more-than-100 American dental periodicals are chiefly of the bulletin type, and of no significance in the progress of dental science. The dental periodicals of value to the research worker can be counted on the fingers of one hand. This phase is amply discussed in the above-mentioned report. Improvement in quality may be expected, inasmuch as both the American

[1] Read at a meeting of the San Francisco Section, International Association for Dental Research, November 16, 1933; also at the general meeting of the Association in Chicago, Mar. 17–18, 1934.

[2] Report of the Commission on Journalism, American College of Dentists, pp. 238; New York, 1932.

College of Dentists and the newly formed American Association of Dental Editors are giving their attention to this phase of dental literature.

Given good dental periodical literature, the next need is means to make its essentials available to as many as possible. In other fields of science availability is assured by abstracts and abstract journals. Unfortunately dentistry possesses no abstract journal,[3] and the restricted abstracting currently performed for various dental periodicals is conducted in a very slipshod fashion. In fact it appears that many editors do not differentiate between abstracts and reviews. An abstract (to draw from) differs from a review in that it contains the essential features of an article. It should consist of concise statements reflecting and condensing the author's opinions and findings. It should never contain views of the abstractor, and must therefore be impersonal and objective. It should not have any superfluous phrases, such as "the author thinks" or "in order to determine the frequency of the occurrence, the author performed a series of scientific experiments which showed that." Such verbosity is useless and the abstractor should write directly: "Experiments showed that. . . . ." A review (looking over again) differs from an abstract in being a critical appraisal of an article that reflects the opinion of the reviewer, hence is personal and subjective. The reviewer may or may not concur with the author; he may summarize the entire article or but a portion of it; likewise the reviewer may draw on his own experience and add new facts necessary to elucidate his views. The abstract or review should give (a) complete title of the paper; (b) name of the author, and perhaps his position or institution; degrees are not necessary; (c) reference—that is, name of the periodical (which may be abbreviated), volume, page, month, and year. In experimenting with various forms of abstracts,[4] especially as to mechanical features involved in printing, I finally concluded that the form used by *Chemical Abstracts* is the most efficient insofar as mechanical features are concerned. A

[3] For some years the American College of Dentists has given attention annually to the desirability of creating a journal of dental abstracts to be known as "*Dental Abstracts.*" Current economic conditions have required postponement of the plans for the establishment of this journal.—[*Ed.*]

[4] *Contact Point*, 5: 140, Jan. 1928; 10: 146, Jan. 1933; 11: 137, Jan. 1934.

printer cannot deviate very much from this form and preserve equal legibility; titles are easily read, the author's name stands out well, and the periodical is differentiated from the rest of the text. The following is an example:

A study of the tubercle on the maxillary third premolar and the mandibular fourth premolar of the dog. TADAS MORI. *J. Nippon Dent. Assoc., vol. 24, p. 452,* Sept. 1931.—Among 85 skulls of dogs captured in Tokyo, 13 showed a tubercle with root on the lingual portion of the crown of premolars, particularly the upper third and lower fourth. Fossils from the tertiary epoch seem to indicate an evolutionary process. Examination of 1 fox, 20 cats, 2 bears, 20 weasels, showed the absence of tubercles in these animals. In the 13 skulls, the occurrence of the tubercle is equally frequent on both sides, but more frequent in the upper jaw. It is ankle shaped and resembles in some cases the lingual cusp of the premolars. Its location was 62.5% in the distal, 29.6% in the middle, 8.33% in the mesial, part on the lingual surface. The tubercle had in 91.6% no complete root, but was attached to the main root. Its origin is probably a swelling of the cingulum.—*Nobuaki Sanada.*

This reference, containing *volume, page, month* and *year,* guards against any possible error, for the *year* checks the *volume,* the *page* checks the *month,* and vice versa. Any one engaged in literary searches frequently finds fragmentary and erroneous references, and is chagrined by the ensuing delay. Dental editors are lax and inconsistent in the matter of references, and thus we find all types of fragmentary references.[5] Likewise the use of Roman numerals should be avoided, for they are obsolete and cumbersome. No one can read Roman numerals as quickly as Arabic numerals. They are always stumbling blocks to rapid work; *e.g.,* xlvii or XLVII versus 47, liv or LIV versus 54.

Even with the best of literature, and the best of abstracts, the literature of any science would be a plumbless ocean and an unsolvable maze unless made accessible by good indexes. Disraeli, in his "Literary Miscellanies," writes forcefully: "I for my part venerate the inventor of indexes; and I know not to whom to yield the preference: either to Hippocrates, who was the great anatomizer of the human

[5] References and periodicals: *Contact Point,* 6: 200–203, March 1929; 8: 176–178, Feb. 1931.

body, or to that unknown laborer in literature who first laid open the nerves and arteries of a book." Each good book has an index and each annual volume of a dental periodical should have an index. But with the exception of the *Journal of Dental Research* and the *Dental Cosmos*, no American dental periodical has an acceptable or efficient index. The *Journal of the American Dental Association* splits the index into various sections: original contributions, editorials, correspondence, contributors, etc., thus complicating any search. Most dental periodicals index not subjects but words. Thus, if the title happens to be "*a case report*," the index-maker places it stupidly under A; perhaps a more advanced one will place it under C or R, for *case* or *report*, respectively. Very few take the trouble to find out whether the "case report" deals with *abarthrosis* or *zymosis*. It is only too common to find in an index such entries as "critical review . . . .," "correction of . . . .," etc., not to mention instances where "the malposed molar" is listed under T. Besides, there are also periodicals which consider an index as superfluous. The index-maker must constantly keep in mind that he has to index subjects and not words. Indexing can thus not be delegated to the new stenographer, but must be performed by one who has a definite and broad knowledge of the subject, or has been trained to pick out subjects.

Far more important than the indexing of a book or periodical is the indexing of a branch of knowledge or a field of science. In dentistry this indexing is performed by the "*Index to Dental Periodical Literature*," of which eleven volumes have appeared, covering the literature from 1839 to 1929. The first volume of the *Index* was published in 1921; the latest, in 1932. The first volume does not differ materially from the latest; both contain, like the intermediate volumes, the same imperfect list of journals, a similar preface, the same so-called "pink sheets" with the same verbal introduction. Measured by the standard of progress, this *Index* has become stagnant. Dental science is a living tree—still growing, not a piece of lumber cut into shape and remaining in that shape until it decays. This growth is reflected in a constantly improving literature; slowly, it is true, but perceptibly. Hence the *Index*, to cover a growing science, must reflect this growth and each new volume should be made better than the preceding one. For instance, the "List of Periodicals" should be improved by incor-

porating more data about each periodical, such as place of publication (early volumes give it, later ones have dropped it), name of editor or publisher, subscription price, addresses, etc., and at least the volume number and year. The pink pages of the *Index* contain the only alphabetical subject index to each volume; and this important section has had the stunted growth from 6.5 pages in 1921, to 7.0 pages in 1932, whereas it should have reached 70 to 100 pages. Although the introduction to this section states in the volumes for 1932 and 1921 that "the following alphabetical index covers practically the entire field of dentistry," one fails to find in the latest volume such items as *pulpless tooth, infection, mouth infection, vitamin, calcium phosphate, phosphorus metabolism, hydrogen ion, acidity, ceramics, refractory, clay, curet, curettage, curettment, root amputation, procaine, soap, allergy, cheilitis, trichomonas, acidophilus, gold foil, vulcanite, panel dentistry,* and a thousand other items. It does, however, list *animal heat* and *leeches*, but not *maggots*.

The very principle upon which the *Index to Dental Periodical Literature* is based is in error, for it is a classified index; that is, an index based upon a system of classification. The purpose of a system of classification is to classify books in a library so that similar books come together upon the shelves, and can thus be kept in a systematic manner. A study of the classification system may likewise be of interest in showing the relation between various branches of knowledge by indicating its divisions and subdivisions. But no classification system, however excellent as such, is suited for an index, because an index should "indicate" or point the way where information can be found—it should not try to impart knowledge as to the structure of a subject and its relationship. An index, in order to be simple and efficient, should be alphabetical. The best index is the socalled "dictionary index," where both the author-entries and subject-entries are in one alphabetical arrangement.[6] To find a subject in such an index requires but a "*key thought,*" a *word* expressing that key thought, and the simple effort to locate that word in its *alphabetic order*—the *only* place where it could appear. In spite of these obvious faults of the *Index*, the bound volumes are a valuable though cumbersome tool for literary search, and they are better than no index at all.

[6] *Contact Point*, 6: 266, May 1929; 9: 265–268, May 1932.

Beginning with the year 1933, the Dental Index Bureau has been issuing a card service that perpetuates all the bad features of the *Index* and in time will become a monstrously unhandy tool. It is mainly to protest against these inefficient cards that this paper is written, because with very little effort the card service could be made an efficient literary aid. Minute details may make or break an index. It is therefore not mere petulance or fussiness that prompts a criticism of the cards sent out by the Dental Index Bureau. (1) The cards themselves lack uniformity; the arrangement of author cards and classified cards are as follows:

year
author
title
journal, vol., page

Author cards

Class No. year
title
author
journal, vol., page

Classified cards

(2) The references are improper; thus we find "*Research Journal* (*Dental*), *XIII, 311–322,*" which is objectionable because the name of the periodical is neither "*Dental Research Journal*" nor "*Dental Journal of Research*"—both of these guesses may reasonably be made from "*Research Journal, Dental.*" The only correct procedure in abbreviating a periodical is to show the correct sequence of essential words in its name; e.g., either "*J. Dent. Research,*" or "*J. D. Res.,*" or any other suitable abbreviation. Arabic numerals are preferable to Roman numerals. Year and month would safeguard against errors. Thus the completed reference should be somewhat like: *J. Dent. Research, 13: 311–322, Aug. 1933.* (3) The most objectionable feature of the cards is the classified arrangement, by which certain classes become so large that within a few years hundreds of cards will have to be read before a desired title can be found. It is also made complicated by the fact that different persons classify differently; e.g., why should "Women in dentistry" come under "Education?"

A dictionary card-index is much more efficient and simple. Thus there are uniform author cards and subject cards, both being filed in one alphabetical order. An example will show this:

author
title
journal, vol., page, mo., year

Author card

subject
author
title
journal, vol., page, mo., year

Two or more subject cards

In order to index a certain article, three or more similar cards are prepared, one being used as the author card (if there are two authors, two will be needed), and the others transformed into subject cards merely by writing a subject above the author's name. Thus the author card:

Forbes, J. C.
Solubility of enamel
J. Dent. Research, 13: 349–362, Oct., 1933

is naturally filed under F in its alphabetic order, while similar cards are made into subject cards by writing above the author's name, "*Enamel, solubility of*" on one card and "*Hydrogen ion, effect upon enamel,*" "*Decalcification of enamel,*" "*Bacteria, effect upon enamel,*" and "*Saliva, effect upon enamel,*" on other cards. Frequently subjects not mentioned in the title will be indexed. This method has been used in our College library[7] for about eight years; and with the help of the junior class, a large card-index to current periodicals has been built up. This is used without difficulty by students, faculty, and practising dentists alike; and does not require individual instruction or key numbers, as required by the classified index.

That this method is in harmony with the best library practice is shown by the fact that the latest Annual Report of the Smithsonian Institution[8] contains, in the Librarian's report, the statement that the most important work undertaken in the past year by the Smithsonian Library is the beginning of a dictionary index on Library-of-Congress

[7] A card index: *Contact Point*, 5: 216–217, March 1928.

[8] *Ann. Rep. Smithson. Inst.*, 1932; pp. 82–83.

cards. The *Index Medicus*, *Chemical Abstracts*, *Science Abstracts*, *Poole's Readers' Guide*, *Industrial Arts Index*, and many other important and extensive indexes are strictly of the alphabetical type. Many university libraries are changing or have altered at considerable cost their classified card catalogs to the dictionary catalog type. These developments justify the opinion that the card service of the Dental Index Bureau should issue a dictionary index consisting of uniform author cards and subject cards, and not continue to inflict an obsolete and discarded method of indexing upon our dental colleges. In a recent questionnaire sent to dental librarians it was found that a majority of them are aware of the advantages of the dictionary index: 3 dental school librarians, representing 354 students, prefer the classified index, but 23 dental school librarians, representing 4407 students, prefer a dictionary index—as does also the Army Medical Library and the Library of Congress.

INTERNATIONAL ASSOCIATION FOR DENTAL RESEARCH

Organized: New York City, Dec. 10, 1920. Of those at the meeting of organization, the following remain active members: Adolph Berger, Theodor Blum, G. W. Clapp, H. S. Dunning, W. J. Gies, H. W. Gillett, R. G. Hutchinson, Jr., T. P. Hyatt, Milo Hellman, F. C. Kemple, A. H. Merritt, B. B. Palmer, P. R. Stillman, L. M. Waugh.

General meetings have been held on this schedule: (1) New York, Dec. 21, '22. (2) Chicago, Mar. 7, '24. (3) Chicago, Mar. 20, '25. (4) Chicago, Mar. 26, '26. (5) New York, Apr. 19, '27. (6) Washington, Mar. 25–28, '28. (7) Chicago, Mar. 23–24, '29. (8) Toronto, Mar. 24–26, '30. (9) Memphis, Mar. 21–22, '31. (10) Columbus, Mar. 19–20, '32. (11) Chicago, Mar. 18–19, '33; adjourned executive session, New York, May 25, '33. (12) Chicago, Mar. 17–18, '34. *Next general meeting* (13): Chicago, Mar. 16–17, in coördination with the twelfth annual meeting of the American Association of Dental Schools, Mar. 18–20, 1935.

Objects (Const., Art. II): . . . "(a) To promote broadly the advancement of active research in all branches of dental science and in related phases of the sciences that contribute directly to the development of dentistry, and which add to the knowledge of the mouth and teeth and of their relations to the body as a whole; . . . (b) to encourage and facilitate coöperative effort and achievement by, and mutual helpfulness among, investigators in all nations in every division of stomatology; (c) to the end, particularly, that dentistry may render cumulatively more perfect service to humanity." (The Association has been using "dentistry" and "stomatology" as synonyms.)

Membership: total (Apr. 15), 360. *Eligibility (Const., Art. 14, Sec. 1).*—"Any person who has conducted, and published an account of, a meritorious original investigation in dental science, or in any of the sciences contributory to stomatology, shall be eligible to membership in this Association, providing such person conforms to the recognized standards of professional ethics." *Election.*—New members may be elected *only at general meetings of the Association.* Membership in a section is secondary to membership in the Association as a whole. Removal of members from one geographic center to another does not affect their membership in the Association.

General officers (1934–35): *Honorary Vice-presidents*—Evelyn Sprawson, London; Hermann Wolf, Vienna; Jan Jesensky, Prague. *President*—J. L. T. Appleton, Jr., Univ. of Pennsylvania. *President-elect*—Theodore B. Beust, Univ. of Louisville. *Vice-president*—William G. Skillen, Northwestern Univ. *Treasurer*—Bissell B. Palmer, Fifth Ave. Hosp. (N. Y.). *Secretary*—William J. Gies, Columbia Univ.

Endowment fund (as of April 21, 1934): $1,119.23. There have been no expenditures from this fund. *Trustees*—The Treasurer; Arthur D. Black, Northwestern Univ.; Russell W. Bunting, Univ. of Michigan.

Divisions may be organized by the members in any nation. There are now divisions in Austria, Canada, China, Czechoslovakia, England, Hungary, South Africa, and the United States—8. *Sections* may be organized by the members in geographic centers within the divisions. There are now sections (26) in Vienna ('29); Halifax ('28), Toronto ('21), Winnipeg ('30); Chengtu ('34); Prague ('32); London ('31); Budapest ('34); Johannesburg ('34); Ann Arbor ('23), Baltimore ('33), Boston ('20), Chicago ('20), Cleveland ('30), Columbus ('32), Louisville ('32), Minnesota ('28), New Haven ('30), New York ('20), Philadelphia ('28), Pittsburgh ('28), Richmond ('33), Rochester ('33), St. Louis ('28), San Francisco ('24), Washington, D. C. ('31). The names of the secretaries are given on p. 2 of this cover.

Sectional meetings in 1933–34 (schedule subject to revision). Ann Arbor—May ?. *Baltimore*—Oct. 24, Nov. 15, Jan. 31. *Boston*—Nov. 6, Jan. 29, May 21. *Chicago*—Oct. 27, Jan. 26, May 18. *Cleveland*—Feb. 12. *Columbus*—Mar. 9. *Halifax*—Nov. 19, Jan. 25, Mar. 14. *London*—Oct. 18, Dec. 6, Jan. 24, Apr. 18. *Louisville*—May 11. *Minnesota*—Nov. 20, Jan. 22, Feb. 26. *New York*—Dec. 7, May ?. *Philadelphia*—Oct. 13. *Pittsburgh*—Oct. 2, Nov. 6, Dec. 4, Jan. 8, Mar. 19, May 7. *Prague*—Jan. 12, May ?. *Richmond*—Nov. 18, Apr. 18, May 26. *Rochester*— Oct. 13, 27; Nov. 10, 24; Dec. 8, 22; Jan. 5, 19; Feb. 2, 16; Mar. 2, 16; Apr. 13, 27; May 11, 25. *St. Louis*—Nov. 14, Jan. 9, Apr. 10. *San Francisco*—Nov. 16, Jan. 24, Feb. 28, Mar. 28, Apr. 25. *Toronto*—July 17, Sept. 12, Oct. 20, Jan. 18. *Washington*—May 3. *Winnipeg*—Feb. 7, May 28.

JOURNALISM IN THE DENTAL SCHOOLS

Below we give three quotations from journals published by dental students. These journals represent the insight, idealism, courage, and professional purpose of a coming generation of dental editors. Dental-school journals are practical agencies for the development of future leaders in dental journalism—leaders who will care more to serve the public causes of a profession than the private interests of a trade-house. We commend such editors to the consideration of dental faculties, and the dental-school journals to the support of dentists generally.

". . . . The editors and publishers of proprietary journals claim that their journals are published for the good of the dental profession and not with an eye to the promotion of the trade houses and dental products of their owners. The editor of one prominent proprietary dental magazine has gone so far as to assert that his particular publication appears "in the interest of the patient." . . . . All periodicals are published primarily for their owners. . . . . But what of the underlying motive? A trade-house owner will take care that his products are not slighted and a publishing house owner will not allow his books, or their authors, to be slighted. A journal published by a dental society is likewise published for the benefit of its owners; and who are its owners but members of the dental profession? Such a journal is published for dentists in fact, not merely in dedication. Therein lies the real difference between proprietary and non-proprietary journalism. . . . ."—*Editorial: Penn Dental Journal, 1934*, xxxvi, pp. 87–88; Jan.

"To the undergraduate it may seem incredible . . . . that the profession of dentistry should have had to depend upon a non-professional group of advertisers, or upon a few commercially subsidized dentists for its literature. Yet . . . . the profession has been needlessly and—worse—carelessly allowed to become dependent upon a purely commercial combine for its fundamental right of expression. . . . . Although this present generation of students cannot remember the effective suppression of the proprietary dental schools in America, we may perhaps be fortunate enough to see dentistry finally strike off the shackles of proprietary journalism, with its garbled commercial sophistry, and watch it emerge a truly unified and universally respected profession."—T. C. Agins, '34: *Tufts Dental Outlook*, 1934, viii, pp. 15–17; March.

". . . . For a magazine like *Dental Survey* to present a medal to some dentist appears like a rather nice gesture. It might be looked upon á bit askance, perhaps, but there isn't anything really wrong about it. But, when this medal is given and the award made in line with the magazine's usual policies of commercialism, we're inclined to view it a little differently and question the professional ethics of the dentist who is editor of the magazine. And it follows, 'as the night the day,' that we likewise question the professional integrity and ideals and ethics of the 'prominent' dentists who aid and abet such a proceeding. . . . ."—T. McB.: *Dental Rays* (School of Dentistry, University of Pittsburgh), 1934, ix, p. 35; March.

INFORMATION FOR PROSPECTIVE SUBSCRIBERS OR CONTRIBUTORS

THE JOURNAL OF DENTAL RESEARCH is dedicated to the advancement of research, and to the dissemination of knowledge, pertaining to the teeth and mouth and to their relations to the body as a whole. It publishes original investigations and reviews in these fields, and in the sciences allied with or applied to them. Although without a "policy," the JOURNAL represents an unwavering purpose to keep widely open the channel to freedom of *responsible* and *respectable* expression of truth and opinion, by individuals or organizations, without qualification by or for any views its editors individually may entertain. Issued bi-monthly, at the *ends* of the months of February, April, June, August, October and December, each volume contains at least 500 pages, for which the subscription price is $5.00.

THE JOURNAL OF DENTAL RESEARCH circulates widely among the most enlightened and progressive dentists and physicians, and among the leading libraries, thus assuring the degree and quality of publicity for its contents that the best dental literature merits. Therefore there can be no important occasion, except in very special instances, for the detailed presentation elsewhere of a paper published in this JOURNAL. Accordingly, to prevent waste of the JOURNAL'S resources in needless duplicate publication, and also to lighten the labors of students of the literature of dentistry, papers in this JOURNAL are not published in, or reprinted from, other dental journals, except for unusual professional reasons. Reprints in any number may be obtained at prices that will be quoted on request.

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